Environmental effects of improved household energy efficiency

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1. Introduction

This report forms part of a synthesis of research on energy-efficiency in low-income urban households in South Africa. The research falls under the Energy and Development Research Centre's project entitled *Energy efficiency, equity and environment: Improving access to energy services for the urban poor of South Africa* (E4 project) which was co-sponsored by Eskom and the International Research Centre (Canada).

Research and practical experience has shown that there are a range of negative environmental impacts associated with the production and consumption of different forms of energy. This report summarises the physical environmental impacts of using different types of energy and assesses the environmental benefits of specific energy efficiency improvements in low-income households in South Africa.

The report draws on and synthesises analysis on the environmental implications of individual energy efficiency interventions which was undertaken during the course of the E4 project. This includes research by Simmonds (1997) on energy-efficient housing, Clark (1997) on energy-efficient lighting, and Borchers (1997) on fuel-switching strategies. In addition, this report draws on work by Van Horen (1996a; 1996b) which focuses on the extent and value of environmental impacts associated with energy use in South Africa.

Section 2 describes the environmental impacts associated with the range of different fuels used in South Africa. Section 3 presents information on the extent and cost of specific environmental impacts for the different fuels used in low-income households. Section 4 details the three strategic interventions – fuel switching, thermally efficient housing and energy efficient lighting – focused on in the E4 project. The potential energy savings and related environmental benefits resulting from these interventions are highlighted.

2. Environmental impacts

This section details the environmental impacts associated with the use of different forms of energy – paraffin, coal, liquefied petroleum gas (LPG) and electricity – in South Africa. The focus of this report is on domestic environmental impacts and, therefore, does not include the impacts of greenhouse gases from energy production, transmission and consumption on climate change. For a comprehensive study on the potential for emissions reduction through energy efficiency interventions in low-income households, see Praetorius and Fecher (1998).

2.1 Impacts of paraffin use

Borchers (1997) identifies paraffin as an economically costly fuel for most purposes, yet it is one of the more widely used fuels in poor urban households. This contradiction between behaviour and economic logic highlights the complexity of the influences on energy-related decision-making for households. The extensive use of paraffin appears to be driven by the fact that it is suited to low-income household budgets. The capital costs of paraffin appliances are relatively low, paraffin is available in a variety of quantities, and the fuel is versatile and readily accessible. There are, however, also significant environmental impacts associated with the use of paraffin. These include:

- health impacts associated with paraffin ingestion and combustion, as well as from accidental fires; and
- property destruction resulting from fuel-related fires.

Further impacts occur as part of the extraction of fossil fuels and the production and refining of paraffin. It is, however, difficult to separate out the impacts directly attributable to paraffin as the fuel is produced in 'parallel' to other products such as petroleum, lubricants and various solvents. Further research is required to assess the impacts resulting from these processes.

2.1.1 Health impacts

2.1.1.1 Impacts resulting from pollution

The more significant by-products of paraffin combustion are nitrogen dioxide, particulates, carbon monoxide (CO) and polycyclic aromatic hydrocarbons. Exposure to these pollutants in significant quantities can have severe health impacts, resulting even in death. While many households cite negative health impacts, such as eye irritation and headaches, from paraffin use, comparative medical studies show the impacts of pollution from paraffin to be small relative to other fuels such as wood and coal. In a survey involving 150 women who cooked with biomass fuels and 75 women who cooked with paraffin, it was found that respiratory abnormalities were much more common among the women using biomass fuels (19%) than the women using paraffin (5.8%) (Terblanche et al 1992). In a study of risk factors associated with household fuel usage in South Africa, Terblanche and Pols (1994) found that in the study group of children between the ages of 8 and 12, the risks of contracting upper and lower respiratory infections (URI and LRI) varied with different fuels. There was an 8 times lower risk to children living in paraffin-using households as compared with coal-using households. Due to the relatively lower levels of pollution from paraffin combustion as compared with biomass fuels, research and policy has tended to focus on evaluating and ameliorating the health impacts in coal-using households, while the impacts of paraffin pollution have been poorly researched.

For example, in South Africa, CO poisoning has most commonly been associated with the use of coal in open fires indoors. A recent study conducted in Kutlwanong, Kimberley, however, showed high levels of CO being emitted from paraffin burners (see Table 1 below). High levels of CO in the sample shacks using paraffin was attributed to poorly maintained stoves (other studies, for example Sejake (1998), have shown that the most commonly used paraffin stoves are of sub-standard quality and are thus likely to result in negative health impacts) and inadequate ventilation. While the study represented a relatively small sample, it points to the need for further research.

Type of apparatus	Usage	Findings
Single paraffin burner	Heating and cooking	CO levels were found to be high (40 ppm – 300+) in 50% of the shacks. High level of odour in most shacks. Old or poorly maintained apparatus. Poor flame combustion especially when placing a pot on top of the stove/heater. No chimneys were found in the shacks with paraffin heaters.
Double paraffin burner	Heating and cooking	CO levels were found to be highest (40 ppm – 600+) in 50% of the shacks. High level of odour in most shacks. Old or poorly maintained apparatus. Poor flame combustion especially when placing a pot on top of the stove/heater. No chimneys were found in the shacks with paraffin heaters.

Table 1: Preliminary findings of Kutlwanong study
Source: PEER Africa (1997)

The health impacts of CO poisoning are severe, resulting in poor health, impaired activity and even death. Table 2 summarises the effects of CO poisoning at different levels of exposure.

Concentration of CO in air (ppm = parts per million)	*Approximate inhalation (breathing) time and toxic (poisonous) symptoms developed*
50 ppm	The maximum allowable concentration for continued exposure for health adults in any 8-hour period, according to the US Occupational Safety and Health Administration
200 ppm	Slight headache, fatigue, dizziness, nausea after 2-3 hours
400 ppm	Frontal headaches within 1-2 hours, life threatening after 3 hours
800 ppm	Dizziness, nausea and convulsions within 45 minutes. Unconsciousness within 2 hours. Death within 2-3 hours.
1 600 ppm	Headache, dizziness and nausea within 20 minutes. Death within 1 hour
3 200 ppm	Headache, dizziness and nausea within 5-10 minutes. Death within 25-30 minutes
6 400 ppm	Headache, dizziness and nausea within 1-2 minutes. Death within 10-15 minutes.
12 800 ppm	Death within 1-3 minutes.

Table 2: The effects of carbon monoxide (CO) poisoning
Source: PEER Africa (1997)

2.1.1.2 Impacts resulting from paraffin ingestion

Paraffin is a very accessible fuel that is easily obtainable through both formal shops, and through informal spazas in the townships. The latter often have long opening hours, and often offer the fuel for sale in variable quantities that make it affordable to those with limited budgets. It is this versatility that may lead to certain environmental problems. At spaza shops, paraffin is sold in a variety of containers, often old beverage bottles. Some infants mistake the bottles' contents for juice or water, and ingest the paraffin. Such accidents are most common in infants between the ages of 12 and 36 months (De Wet et al 1994; Ellis et al 1994 in Van Horen 1996). The health impacts of paraffin ingestion or inhalation range from coughing and choking, to diarrhoea and vomiting and possibly even death.

Drawing on Yach (1994:717), Van Horen (1996) uses a figure of 16 000 cases per year (correlating with approximately 30 cases per million litres of paraffin sold) as a central estimate of the number of hospitalised cases of paraffin poisoning. An incidence range of between 1% and 6.5%, based on the results of health and safety surveys carried out by Terblanche et al in 1992 and 1993, is applied to the estimated 2.9 million paraffin-using households to produce low and high estimates of 5 800 and 37 700 hospitalised cases per year. Of these cases, 1.3% are assumed to result in death. Based on the central estimate of 16 000 cases per year, this amounts to 208 deaths per annum, with low and high estimates of 75 and 490 per annum respectively. These estimates are based on national figures which include both rural and urban populations. Studies have indicated that the incidence of paraffin poisoning is higher in rural than in urban areas (Ellis et al 1994). The fact that approximately 75% of poor households occur in rural areas would therefore suggest that at least as great a proportion of total morbidity and mortality due to paraffin poisoning occurs in these areas.

Paraffin poisoning is cited as being the most common cause of childhood poisoning in South Africa (Ellis et al 1994; De Wet et al 1994; Korb & Young 1985 in van Horen 1996). Paraffin is, however, not a notifiable poison and, therefore, not all cases are reported. Of those which are reported, only a portion are hospitalised, with a large number of these reported cases being treated as out-patients. The extent of paraffin poisoning may, therefore, be even more severe than estimates suggest.

2.1.1.3 Impacts resulting from fires and energy-related accidents

A retrospective analysis undertaken on 194 patients admitted to the Burns Unit in Woodstock Hospital, Cape Town between January 1990 and June 1992 found that 33 patients sustained burns as a result of working with primus stoves (Hudson et al, 1994:

251). What is notable is that these patients were all black men and women ... Medical research has found that more children than adults suffer from paraffin-related burns, mainly caused by residential fires ... There is general agreement that burns – resulting from the use of domestic energy sources (mainly paraffin) – are one of the top causes of injury and mortality in the under-14 age group (Mehlwana 1998: 1)

In the absence of national data relating the incidence and effect of energy-related fires, Van Horen draws on 1990 census data which records 2 646 deaths caused by burns amongst black South Africans (Lerer 1995: 23). Assuming that two thirds of these were caused by energy related accidents, he calculates that this translates into 1 773 energy related fatalities in 1990. He proceeds to correct this for the increase in electrification that had occurred up to 1994, estimating the total number of energy related burn fatalities to be 1 330. It must be noted that this figure also includes energy related burn fatalities from sources other than paraffin, such as candles and gas. Candles could account for as much as 70% of the fires and thus fatalities (Van Horen 1997). The low and high estimates for the number of burn fatalities are 208 and 1 596 per annum.

The number of non-fatal burn injuries can be estimated by quantifying the number of burn-related admissions. This, however, does not reflect the severity of the burns sustained. Van Horen (1997) calculates a central estimate of 8 736 admissions during 1994, and assumes that the low and high estimates will deviate by 33% from this figure to produce figures of 5 853 and 11 619 admissions respectively. Estimates of burn-related fatalities and hospital admissions are presented in Table 3 below.

Impacts	*Low estimate*	*Central estimate*	*High estimate*
Paraffin related			
- Fatalities	62	399	479
- Hospital admissions	1 756	2 621	3 486
Candle related			
- Fatalities	146	931	1117
- Hospital admissions	4 097	6 115	8 133
Total			
- Fatalities	208	1 330	1 596
- Hospital admissions	5 853	8 736	11 619

Table 3: National estimates of the number of burn related fatalities and hospital admissions attributable to paraffin and candles
(Adapted from Van Horen 1996)

2.1.2 Displacement and loss of property resulting from fires

The fire – the second in four days – is believed to have started at 1 am. The fire continued to blaze until 5 am when it was finally overcome. It took a total of six fire brigade trucks to dowse the fire. By 6 am, 25 shacks had been burned to the ground – and more destroyed, as people had to dismantle a number of shacks in order to contain the fire. Fortunately, there were no major casualties save for a few burns, but the loss in terms of property was immense.... A paraffin lamp that was left burning by children is said to have caused the fire. (Mehlwana 1998: 7)

While no national studies have been conducted to determine the extent of damage caused by energy-related fires, media reporting of fires, particularly in informal settlements, indicates that it is a severe problem in South Africa. The risks associated with the use of energy sources such as paraffin, gas and candles are heightened in informal settlements because of the high incidence of flammable materials used in shack construction and the high density of the settlements.

Complete shacks can burn down in a matter of minutes and the fire can very quickly spread to adjacent shacks. In a single review of a local newspaper that reports on the northern parts of the Cape Metropolitan Area (*Die Burger*), van Horen was able to find articles that showed that at least 978 shacks had been destroyed by fire in 1994, mostly occurring in the two informal settlements of Marconi Beam and Town B of Khayelitsha. In his article entitled *The anatomy of disaster: Case studies of health and safety aspects of fuel use in poor communities*, Mehlwana (1998) highlights the high incidence of fires in Joe Slovo, an informal settlement in the Cape Metropolitan Area, and the severity of the social impacts associated with those fires. In the period of a year, seven fires ravaged the community of Joe Slovo destroying a total of 153 shacks and temporarily displacing 498 people (see Table 4).

Date of fires	*No. of shacks burned*	*No. of people displaced*
04 March 1996	34	108
26 July 1996	12	48
01 September 1996	18	65
10 September 1996	14	40
17 December 1996	13	42
13 January 1997	26	85
16 January 1997	36	110
TOTALS	153	498

Table 4: Fires in Joe Slovo between March 1996 and January 1997
Source: Mehlwana (1998)

The consequences of these fires for poor communities are huge in terms of both material loss and social costs. With neither insurance nor capital to replace their belongings or rebuild their homes, fires put substantial stress on the livelihood strategies of poor individuals and households. The case of Dumisa demonstrates how his strategy to build up his home, accommodating intermittent income, was destroyed by a fire.

> A shack belonging to Dumisa, a single and recently unemployed man, was burned down. On Monday following the fire, we located him sifting through the debris, trying to find some building material that he could re-use to build a new shack. He had come to Joe Slovo in the middle of 1996 after he received employment. Before that, he lived with relatives in a hostel shack in Langa. The casual employment had soon ended. 'I had invested a lot on this shack because I knew that my work is not going to last for long', he reminises. He said he had bought furniture – bed, chairs and clothes, 'now everything is gone' … 'I watched as everything I worked for was taken by fire.' (Mehlwana 1998: 6)

For those who cause the fires, whether by accident or design, the consequences are even more severe. Individuals are required to pay for the property of the victims of the fire. If they are unable to do so, they may be severely beaten and evicted (Mehlwana 1998). Again, this can place severe stress on the livelihood strategies of these households. The case of Siphimiwe recalled by his girlfriend further demonstrates the burden of fires on poor communities.

> After the fire there were problems for us. We were called to a meeting to explain what caused the fire. The problem was that we had to pay back this woman whose 'house' was also burned. Siphimiwe had just to work. We had a new baby – and things were starting to go well for us. Now we had to pay back whatever that woman lost .... We paid her R500.... Imagine if more houses were burned. We would be out of this area by now. (Mehlwana 1998:9)

2.2 Impacts of electricity use

The environmental impacts of electricity can be divided into three basic categories, namely those impacts that occur at the point-of-use, those that occur as a result of the transmission, and those impacts that occur with the generation, of the electricity.

2.2.1 Impacts at point-of-use

Electricity is a non-polluting source of energy at point-of-use. It is, therefore, seen as having the potential to reduce household environmental impacts, particularly pollution levels, by displacing other sources of energy such as coal and wood in the domestic environment. The extent to which electrification will have a positive impact is influenced not only by the qualities of electricity, but also by the level of displacement, and the type of fuel (and the associated environmental impacts) it displaces. In addition to the potential to reduce indoor air pollution, many positive social impacts have been associated with switching to electricity. One such example is that electricity can provide better light than candles or paraffin lamps, thus enabling households to engage in productive activities, such as studying or small business enterprises, after sunset.

There are also certain negative environmental impacts at the household level associated with the use of electricity. While electricity is generally considered a safe fuel, fires have been caused by electrical faults, and there have been a number of cases of electrocution. Some of these accidents can be attributed to poor wiring or to dangerous, illegal connections. Insufficient research has been undertaken into the extent of these impacts and, therefore, it is not possible to assess the extent of the problem.

2.2.2 Impacts of electricity transmission

Activities associated with the transmission of electricity can be split into three components, namely construction of transmission lines and sub-stations, line maintenance and transmission. Impacts associated with these include accidental electrocution, electromagnetic radiation, displacement of people, loss of productive land, and the loss and disturbance of flora and fauna. Appropriate planning can significantly control the impacts associated with transmission lines, their peripherals and their construction and maintenance. Eskom have been proactive in recent years, requiring detailed environmental impact assessments (EIAs) of new projects and following these through with environmental management plans (Pillay 1997).

It is difficult to generalise about the impacts of electricity transmission because of the broad range in types of transmission (ranging from between 220kV to 380kV (reticulation) through between 11kV and 22kV to 765kV), the different technologies and structures associated with them and the wide variety of environments through which they pass. The scope of this study is unfortunately unable to consider localised impacts such as the disturbance of rare fauna and flora, and is thus not able to quantify the probable impact of a national increase in electricity transmission. An extensive Geographical Information Systems (GIS) study correlating existing transmission lines and the environments they pass through might go some way to quantifying the national extent of the impacts associated with electricity transmission, but the scope of the data that would have to be collected makes such a project improbable.

2.2.2.1 Electrocution

While there is no formal record of the number of accidents and human fatalities resulting from electrocution from transmission lines, Eskom are currently building up a database on reports of animal accidents with transmission lines (Naidoo 1997).

2.2.2.2 Impacts of electromagnetic fields

Research into the health effects of exposure to electromagnetic fields generated by power lines is on-going and covers a wide area of interest, including its links to various cancers, reproductive outcomes, depressive symptoms and headaches (Scholand 1997). While some studies have indicated that people who work in electrical occupations have higher than average leukaemia and brain cancer rates, others have shown a correlation between power lines and cancers in children living nearby. The correlations are, however, not strong and the evidence linking electrical power lines to cancer is not conclusive. Epidemiological studies that show a relationship between cancer and power lines do not provide any consistent guidance as to what distance or exposure level is associated with increased risk. Furthermore, other environmental factors may obscure the results. For example, power lines frequently run along major roads and some studies indicate that traffic densities correlate with childhood leukaemia. Power lines could thus be a surrogate for cancer-causing substances in traffic exhausts (Scholand 1997). The International Radiation Protection Association does, however, set safety guidelines of 100μT for continuous public exposure and 5 000μT for short term occupational exposure. Preliminary studies in South Africa have shown that recorded levels of electromagnetic radiation are well below the recommended guidelines for continuous public exposure and the conclusion drawn from live-line worker data was that the dosages received were 'less than remotely significant' (Lennon et al 1994).

2.2.2.3 Impacts related to the clearing of servitudes for transmission lines and substations

Impacts of the clearing of servitudes for transmission lines and substations can include the displacement of people, their activities and assets, as well as the destruction of flora and fauna.

- ***Displacement of people:*** While the clearing of servitudes could result in the displacement of people and cultural heritage sites, Eskom does undertake EIAs in an attempt to minimise the impact through consultation with local populations.

- ***Loss of productive land:*** The extent of loss of productive land is dependent on current and potential land use activities. Where transmission lines pass through commercial forests, for example, they require that a certain servitude be kept clear of any tall vegetation and thus that revenue and aesthetic value is lost. This does not apply to the same extent for areas under cultivation of crops such as maize, or for land used as grazing. For these types of land use, only the small patches of land where the pylons are placed are lost from production and thus there is minimal cost to the land user.

- ***Impacts on fauna and flora:*** The impact on fauna and flora can be either positive or negative. Potential negative impacts include the loss of flora and habitats, as well as the fragmentation of habitats. Potential positive impacts include the creation of edge communities, new habitats for greater variety of fauna and flora, and the linkage of habitats fragmented by other human activities. The type of impact that occurs will be dependent on the nature of the area, the way in which clearing is conducted and the management of the servitudes.

Table 5 below indicates the total area covered by servitudes, but is unfortunately unable to correlate this to any type of land use. This paper is, therefore, unable to assess the environmental costs of these transmission lines.

Line type	Line capacity	Length of line (kilometers)	Width of servitude (meters)
Main transmission system	765 kV	1 153	45 to 55
	533 kV DC	1 035	47 t0 55
	400kV	14 216	51
	275 kV	7 130	45 to 55
	220 kV	1 239	45 to 55
	132 kV	653	31
Distribution lines	165 – 132 kV	18 730	31
	88 – 33 kV	20 597	22
Reticulation lines	22 kV and lower	190 992	18
Cables	Various	6 057	Various

Table 5: Types of transmission line and associated servitude width

2.2.2.4 Impacts associated with construction activities

There are many potential impacts associated with the construction of power lines. The extent of these impacts depends on the type or size of the line, the characteristics of the area they pass through, and the way in which the construction activities are managed or conducted. The size of the line influences the amount of vegetation clearing required, the type of equipment brought into the area (which in turn influences the size of the access roads that will have to be built), and often the size and discipline of the construction team (that is, the extent to which they pollute the area, or participate in activities such as poaching or disturbing the local population). The construction practices, such as how clearing takes place (using biocides or hand labour) and the extent to which rehabilitation of borrow pits are carried out, will be an important determinant of the eventual impact of construction. If EIAs continue to be undertaken and their recommendations correctly applied to these activities, the impact of these activities on the environment can be minimised.

2.2.2.5 Impacts associated with line maintenance

The maintenance of transmission lines requires that the lines be accessible at all times, at least by four-wheel-drive vehicles. In some instances, activities such as insulator cleaning on the larger lines can be accomplished by helicopter. This is, however, a costly exercise. The access roads constructed to facilitate line maintenance can result in the disturbance of vegetation (destroying habitats and promoting erosion). In addition, line maintenance activities may have certain socio-economic impacts. For example, the introduction of access roads can promote migration into or out of the region, either bringing income to the region or placing stresses on the biophysical and social environments.

2.2.2.6 Transmission versus transport

One of the most attractive features of electricity is that it is able to be transmitted via a grid rather than by road or rail. Potential environmental and social advantages of grid transmission include:

- The grid infrastructure means that there is less stress on road and rail transport. As a result a number of environmental impacts associated with the transport industry are avoided. These include noise and air pollution from vehicles, erosion from road and rail construction, accidents, and the displacement of people or fauna and flora.
- Transmission does not require direct expenditure on imported crude oil. This does not mean that transmission occurs without any energy cost. There are energy losses of between 6 and 10 percent of the total transmitted (Eskom 1996).

2.2.3 Impacts of coal-based electricity generation

Ninety-two percent (92%) of South Africa's electrical energy is generated by the state utility, Eskom. Most of this electricity (approximately 92%) is generated by 10 coal-fired power stations. The remaining power is generated by a single nuclear power station (7% of power generated), two pumped storage plants (0.8%) and two hydropower facilities (0.3%). A surplus generating capacity exists in the form of a number of mothballed coal-fired generators. These are being recommissioned over a period of approximately fifteen years, beginning at a rate of approximately 950 MW per year for the period 1996 to 1999. A total of 670 MW each is to be recommissioned in the years 2000 to 2001, and a further 864 MW, 1 488 MW and 903 MW are to be recommissioned in the period spanning 2008 to 2010. Parallel to this, Eskom intends to import 1 300 MW per year over the next seven years, increasing this to 1 800 MW per annum as of 2004 (Eskom 1996). These imports will be sourced primarily from the Cahora Bassa hydro generators. The overall electricity generation picture, therefore, remains one dominated by coal. Considering South Africa's electricity supply-mix is likely to be dominated by coal-based power stations in the near future, we consider it appropriate in this report to focus on the externalities associated with coal-based generation.

The impacts of coal-based generation include:

- health impacts from air pollution;
- impacts of acidic deposition on forests, crops, buildings and other materials sensitive to acidic corrosion;
- visibility impacts of air pollution;
- impacts on the quantity and quality of water resources

2.2.3.1 Impacts of air pollution from coal-fired power stations

The *extent* of air pollution at a given point is not only dependent on the volume of emissions, but also on the type of emission, the opportunity for pollutants to combine, the prevailing weather conditions (which influence the dispersal of the pollutant), and the geographic location relative to pollutant sources. The concentration of pollutants can, thus vary considerably in time and space. The *impact* of those pollutants is, in turn, dependent on pollutant concentration relative to an appropriate threshold, pollutant type, the period of exposure, and the condition of the organism (including humans) or object on which it acts. As a result of these variables, it becomes difficult to generalise about the extent or impact of air pollution for large areas, and over long periods of time. When viewing assessments of such impacts, it is prudent to keep this in mind, and to be constantly aware of how often levels exceed the appropriate thresholds.

The range of pollutants emitted from coal-fired power stations include particulates, sulphur dioxide (SO_2), nitrogen oxide (Nox) and ozone (O_3). The concentrations of these pollutants in the areas where coal-based electricity is generated in South Africa is detailed below.

Total suspended particulates (TSPs): The concentrations of particulates over the period 1979 to 1983 were around 17μgm^{-3} while annual guidelines are 150μgm^{-3} (Van Horen 1996). Eskom claim 20% of particulates come from power stations, while 46% come from low level emissions from smouldering coal dumps and local industries. This would seem to suggest that particulates sourced from electricity generation currently do not pose a serious threat to the environment. Turner (1994) does, however, suggest that Eskom reduce its fly-ash emissions (see section on visibility below).

Sulphur dioxide (SO_2): Generally well within annual guideline levels, with averages over the period 1979 to 1986 of around 26μgm^{-3} (Van Horen 1996). By comparison, the South African Department of Health guideline is 78μgm^{-3}. There were, however, more frequent exceedences of guidelines on shorter monitoring periods, but Eskom's more recent studies show no such exceedences at its six monitoring stations (van Horen 1996).

Nitrogen oxide (Nox): The data suggests that this pollutant does not pose a serious problem. Long term concentrations in the 1980s were around 15μgm^{-3} as compared with the long-term guideline of 376μgm^{-3}. In 1993, levels were reported as being below the guideline, but with significant short term peaks (van Horen 1996).

Tropospheric ozone (O_3): Ozone can be formed as a secondary pollutant that is the product of photolytic dissociation of oxygen in the presence of gases such as nitrogen oxide. Eskom's monitoring shows that hourly, monthly and annual concentrations were frequently surpassed during the period 1983 to 1988 (Tumer et al. 1990). Annual averages are two to three times the guideline of 20μgm^{-3}.

Lennon et al (1994) note that despite an increase in total plant emissions (3%) by Eskom, plant efficiencies have increased so that emissions per unit of energy sent out have decreased. They also claim a decreasing trend in Eastern Transvaal Highveld (ETH)[1] pollution levels over the 8 years leading up to 1994, and for this to be largely attributable to reduced burning of coal waste dumps, tall stacks, increased plant efficiency, and the mothballing of some power stations. It must be kept in mind that the pollution levels mentioned above are not solely the product of Eskom's activities. There are a number of other industries such as SASOL and a number of coal mines in the region.

These pollutants have been linked to several impacts which are discussed below:

Health impacts:

Several factors hinder determining the relationship between air pollution and human health. Firstly, it is difficult to isolate the contribution of a particular pollution source to ill health when there are a large number of situations in which individuals could have been exposed to the same type of pollutants or pollutants that have the same effect (for example, through the domestic use of coal and wood or from motor vehicles). Secondly, there is a dearth of dose-response studies to inform such determination. Finally, health impacts are not only dependent on dose, but also on the initial health of the individual, and can thus be expected to be greater for the poor whose economic situation restricts their access to medical services and adequate nutrition. The comparison of air pollution levels with specific thresholds would therefore seem to be the only feasible means of gauging the level of impact of air pollution.

The pollutants described above have been implicated in a number of health problems.

- *Particulates* have been implicated as a cause of cancer of the respiratory and digestive tracts, as well as reduced lifespan and increased infant mortality (Gerson 1992).
- *Sulphur oxides* have been implicated as a cause of pulmonary disease, increased frequency and severity of asthma, and increased incidences of mortality from chronic respiratory disease (Gerson 1992).
- *Ozone and PAN* (products of photochemical reaction) have been linked to pulmonary disease; eye, nose and throat irritation; nausea and headaches; and damage to lung tissue (Gerson 1992).

Impacts of acidic deposition

Processes of wet or dry deposition of pollutants can have a significant affect on objects on the earth's surface. Over and above particulates being able to smother plant life, inhibiting photosynthesis, the dry deposition of pollutants can have an acidic effect, while the combination of pollutants such as SO_2 with moisture in the air forms sulphates which are deposited on surfaces in what is commonly referred to as acid rain. Such acids damage plant

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[1] Now known as the Mpumalanga Highveld.

life (including commercial crops), biota of downstream ecosystems, as well as manmade objects such as buildings and vehicles. According to Van Horen (1996) there appears to be a wide range in the estimates of the wet and dry deposition rates for the Eastern Transvaal Highveld (ETH). Tyson et al (1988) reported wet deposition rates sometimes exceeding 20kg/ha per annum (considered a critical threshold), while monitoring by Eskom over a seven-year period produced a 'reasonably low' estimate (Turner 1993 in Piketh & Annegram 1994: 5). Similarly, estimates of dry deposition rates range from 20kg/ha per annum (Turner 1994b: 6) to somewhere between 49 and 81 kg/ha per year. Van Horen found only one field study (Olbrich and Kruger 1990) that has tried to assess the damage that has occurred in commercial forests in the Mpumalanga Highveld. They observed very small changes, but the evidence was not considered conclusive. It was reported that commercial forests did not appear to have suffered any substantial ill-effects from acidic deposition.

Van Rensberg (1992) deduced that the current levels of pollution in the ETH have a negligible impact on agricultural crops and Harnung et al claim that current farming practices of liming negates the impact related to acidic deposition (Lennon et al 1994).

Gerson (1992) cites a study by Skoroszewski (1990) which found indications of damage to benthic (bottom dwelling) communities in a group of streams along the Drakensberg Escarpment 'that were typical of the kind caused by air pollution'. The affected streams were situated near Newcastle, downwind of major pollution sources in the ETH and PWV region.

Visibility impacts

Reduced visibility is a product of the amount of anthropogenically produced pollutants (for example, particulates from power stations and industry, dust from mining and mine dumps, dust from agriculture and fires), naturally occurring particulates (dust and water vapour), and products of chemical reactions in the air (photochemical smog). An Eskom study in the Mpumalanga Highveld by Turner (1994: 5, 11) for the period 1985 to 1993 shows visibility ranges as follows:

Over 100km on 10% of days measured.
As low as 40km on nearly 50% of days measured.
As low as 30km on over 20% of days measured.
As low as 20km on nearly 10% of days measured.
As low as 10km on 1.1% of days measured (4 days per year).

Eskom's analyses in correlating diurnal visibility conditions with emission patterns from its power stations claim that emissions of particulates and sulphur dioxide by power stations 'do not play a major role in the visibility impairment' (Turner 1994: 6). They point to low level and regional sources, such as smoke from biomass burning, smouldering coal dumps, and surface dust, as the primary cause of reduced visibility. Turner (1994) does, however, suggest that Eskom minimise its flyash output in order that the public's incorrect perception of Eskom as a major contributor to incidents of poor visibility be dispelled.

2.2.3.2 Disposal of solid waste

The electricity generating industry produces some 20 million tons of ash annually (Lennon et al 1994). Three percent (3%) is used to produce cement, while the remainder must be landfilled. Legislation requires that the dumps be fully rehabilitated to self-sustaining ecosystems, and do not pollute the ground water. Problems with dust do however occur in the time that it takes to vegetate the surfaces of the dump.

2.2.3.3 Impacts on water resources

In coal-fired power plants, water is used both to drive the turbines (as steam) which generate electricity and to cool down the steam in cooling towers. Coal-powered electricity is not only a significant consumer of water, but also returns significant quantities of water back to the environment (van Horen 1996). Potentially, therefore, it can impact on water resources in two ways, affecting their quantity and quality.

Quantity of water resources

South Africa is not well endowed with water resources. It is claimed that demands for drinking water could exceed availability by the year 2020 (Presidents Council Report 1991). Availability problems have led to the construction of a number of schemes such as the Tugela-Vaal system, and most recently the Lesotho Highlands Project of which only Katse dam has been built to date.

Two of Eskom's newer power stations use dry cooling towers (a system pioneered by Eskom), thereby reducing the net amount of water consumed. Water consumption has dropped from 262 372 megalitres in 1986 to 214 329 megalitres in 1995. In 1994 Eskom consumed 213 537 megalitres of water, of which 8% (17 083 megalitres) was returned to public streams.

Water quality

Eskom claims to strive for a 'zero effluent' water policy, aiming to return water to rivers and dams in at least as good a condition as the water it draws from the sources. Of the 17 083 megalitres returned to public streams, 10 megalitres did not conform to Department of Water Affairs and Forestry (DWAF) standards. Furthermore, six incidents of leakages, or of rainfall-induced overflows of storage dams, occurred in 1994. Eskom was able to obtain permission from DWAF for these releases.

In some instances, Eskom's need to purify the water it draws from the environment has led to a positive impact in the form of the water it returns to the stream being of a better quality than that which it originally drew off (Van Horen 1996).

Concerning the impact of acid deposition and its effect on the country's fresh water systems' ability to sustain different hydrological ecosystems and suitability for human use, Lennon et al (1992) claim that the high alkalinity of most of the rivers and dams on the ETH negates the risk implied by acidic deposition. The Vaal river has, however, shown significant increases in sulphate concentrations over the last few years (Lennon et al 1994). This is an indicator of acidification but is not necessarily tied to Eskom alone. A Department of Water Affairs and Forestry Water Quality Management report does, however, state that the 'insidious effect of fossil fuel burning that becomes apparent only after a lag-phase of several decades' is a major concern in the long term with respect to its effect on increased salination (DWAF 1991).

2.3 Impacts of coal mining

The impacts that result from coal mining vary with the type of mining practised. Fifty percent (50%) of all coal mining in South Africa is of the board and pillar type (below ground), 35% is open-cast, while the remainder is made up of long-wall mining and pillar extraction (below ground) (Raimondo et al 1995). The water and air pollution that stems from coal-mining activities has been reduced considerably in recent years, mostly due to better management practices on the part of the mines themselves. These improved management practices appear to be driven by licensing provisions which require mining companies to provide Environmental Management Plans and bonds.

Coal is used for a number of purposes in South Africa. Eskom absorbs roughly 40% of total production (55% of the local market – notably the lower grade coal), SASOL consumes roughly 31%, while a further 25% of production is exported. The remainder is used by industry, mining, and transport, while a little more than 1.5% of the total is used by the household sector.

2.3.1 Air pollution

2.3.1.1 Spontaneous combustion in dumps

Although on the decline, spontaneous combustion and the accidental ignition of large dumps of discard coal and near-surface deposits (that is, underground fires) have produced significant amounts of air pollution in the past. The pollutants emitted are generally the same type as those produced from the combustion of coal for electricity generation purposes. These include particulates, SO_2, Nox and O_3, and are discussed in more detail under Section 2.2. Quantities of emissions differ significantly, however. There is no data quantifying emissions or relating specific emissions with specific mines or dumps and thus the apportionment of different impacts is not possible.

2.3.1.2 Dust

Open-cast mines are particularly responsible for particulate matter (dust) pollution. Dust arises from the movement of vehicles, coal, and waste material, as well as from blasting at the coal-face. Such particulates are necessarily contained and filtered in the case of underground mines, localising their effect to the miners. Dust is also generated in the crushing process, while further particulate pollution is generated from underground fires and burning discard dumps.

2.3.1.3 Methane

Methane is released in considerably smaller quantities than CO or CO_2, but is significantly more effective as a greenhouse gas. The Development Bank of Southern Africa (DBSA) claims that coal mining is responsible for the emission of 1 659 347 tons of methane per year (Raimondo et al 1995). This translates into 9.2kg/t of production. Methane has a global warming potential 24.5 times that of CO_2 and, therefore, the CO_2-equivalent for methane emissions from coal mining is estimated to be 40 million tons.

2.3.1.4 Sulphur Dioxide (SO_2)

Fires associated with coal mining are estimated to contribute about 5% to total SO_2 emission in the Mpumalanga Highveld (Raimondo et al 1995). There were 57 burning coal dumps in South Africa in 1991. The remainder of the SO_2 stems from Eskom and local industry.

2.3.2 Water pollution

The effluents and leachates from operating and abandoned mines, and from the beneficiation process are regarded as very serious (Raimondo et al 1995). This is particularly true of the Olifants River catchment area of the Eastern Transvaal. The pollutants can contaminate ground water and surface supplies a considerable distance downstream thereby affecting agricultural and community supplies some distance from the source. Raimondo et al (1995) also note some examples of water pollution that have occurred in the ETH and give some of the associated costs of clean up operations.

> The Klipspruit River in the Witbank area receives contaminated coal field run-off. An estimated 60% of the pollution is from abandoned mines and 40% from operating mines and industry. The Department of Water Affairs & Forestry will be treating the water from 10 abandoned mines at a capital cost of R 16 295 000 and a total operating cost of R4 540 000, totalling R 20 835 000 (for the period 1993/94 to 1996/97).

Furthermore,

> Approximately R 50 million per year is spent in the ETH in clean-up efforts, by the state, of diffuse pollution which cannot be traced to sources.

Unfortunately it is not realistically possible to apportion these incidents of pollution or their costs amongst mining activities that feed either the household, industrial, or the power generating sectors.

2.3.3 Solid waste

Forty-seven million tons of discard are produced per year (Raimondo et al 1995). Associated impacts are a contribution to the dust from mining activities already mentioned above, and the removal of potentially productive land from other use.

2.3.4 Occupational health issues

The occupational health hazards associated with coal mining include industrial accidents (from the transport and handling of materials), mining accidents that lead to immediate injury or death (rock falls, blasting, and methane explosions), and the longer-term hazard of respiratory problems (emphysema and pneumonia) arising from a polluted air environment.

Acknowledging that accident rates would differ between open-cast and underground mines, and that injuries (not fatalities) appeared to be declining, Van Horen (1996) uses the accident data from the Leon Commission (1995) to derive rates for the mines that feed Eskom's coal driven power stations. He estimates that there would be an average of 0.30 fatalities and 1.68 injuries for every million tons of coal mined for purposes of power generation, and that for the 149 443 GWh produced in 1994, a total of 23 workers would have died, and a further 131 would have been injured.

Referring to a number of sources, a Palmer Development Group (1995) study on the potential market for low smoke coal estimated the household coal market to be in the region of 3.3 million tons per annum. Using Van Horen's (1996) estimates of fatalities and injuries for every million tons of coal produced (from underground operations), then household consumption could theoretically only be considered responsible for up to two deaths, and ten injuries per annum.

The Leon commission (1995) also heard evidence that suggests that the effects of prolonged exposure to air pollution are significant. Van Horen (1996) points to tuberculosis, emphysema, hearing impairment, pneumoconiosis, and silicosis as being the most common effects, but that the lack of published studies and dose response relationships makes the quantification of this impact impossible. Likewise it would seem impossible to quantify the emotional and physical pain and suffering experienced by the miners, or that felt by their families.

Table 6 below details the number of fatalities on SA coal mines for the years 1993 and 1994

Fatalities and injuries on SA coal mines										
	Open cast		*Surface*		*Underground*		*Total*		*Fatality rates*	*Injury rates*
	Fatality	*Injury*	*Fatality*	*Injury*	*Fatality*	*Injury*	*Fatality*	*Injury*	*/000 workers*	*/000 workers*
1994	3	20	14	66	38	153	55	239	1.02	4.45
Total labour: 53 717 (underground mining: 29 284; open cast/surface mining: 24 433 A single fire at the Gloria Underground Colliery caused 16 deaths and 1 injury.										
1993	2	17		72	85	199	90	279	1.57	4.87
Total labour: 57 273 (underground mining: 31 853; open cast/surface mining: 25 420 A dust explosion at the Middelbult Colliery caused 53 deaths.										

Table 6: The number of fatalities on SA coal mines for the years 1993 and 1994
Source: Raimondo et al (1995: 50)

2.4 Impacts of domestic coal use

Mention has already been made above of the occupational health hazards associated with coal mining, and that possibly one to two deaths, and ten injuries could be apportioned annually to the externalities that could be associated with the extraction of coal for household use. The discussion below focuses on the local and community level impacts of using coal in the home.

2.4.1 Outdoor air pollution levels

Lennon et al (1994), Tosen et al (1991), and Sithole et al (1991) undertook studies in South African townships to determine the level of air pollution and the potential impact of the pollution on the local and regional environment. Focusing on Soweto, Sharpville and Sebokeng (all townships in the Gauteng region), they found little difference between the non-electrified towns. Van Horen (1996) notes that 'Soweto's air quality has been studied more often than any other township in South Africa, partly because it was so heavily polluted, and partly because electrification was expected to bring about substantial improvements in air quality'. However, he goes on to note that, for 'various reasons, coal continues to be used on a large scale in Soweto and, consequently, air pollution problems remain serious'. Some of the air pollution findings relating to the three townships are discussed below. It should be noted that there is a much greater prevalence of household use of coal in the Gauteng region than in the other major urban centres of Cape Town, Port Elizabeth, and Durban. The figures below should be seen to apply to the Gauteng region only. The medical effects of the pollutants mentioned below have been outlined earlier in this paper.

2.4.1.1 Sulphur dioxde

In Soweto, Sithole et al (1991) found the typical annual SO_2 concentrations to be in the order of 23ppb (compared with the national guideline of 30ppb). However, hourly maximum concentrations of 117ppb were found to occur frequently in winter.

2.4.1.2 Particulate concentrations

Lennon et al (1994) found fine particulate matter (FPM) concentrations to be particularly high in the study areas. Viewing FPM as having a particulate mass of less than 10µg (PM10, that is respirable particulates) they compare FPM concentrations with the US EPA daily and mean annual standards of 150 and $50\mu gm^{-3}$. They state that maximum hourly means of between 800 and $1800\mu gm^{-3}$ are measured regularly in winter in such areas. Turner and Lynch (1992: 2) in Van Horen (1996) noted the strong seasonal and diurnal variations in particulate concentrations to correspond closely to household usage patterns, and with dust from vehicles traveling on unpaved roads. Further evidence pointing to household coal is offered by Tosen et al (1991) who found the FPM concentrations to differ significantly from non-adjacent electrified areas.

Lennon et al (1994) quantify the annual emissions of SO_2, CO_2, and FPM per dwelling as being 5.5, 580, and 95,7kg respectively for the townships mentioned earlier. They couple this with an estimated 250 000 unelectrified dwellings in both Soweto and Sharpville to estimate that the atmospheric emissions would amount to 1 375, 145 000, and 24 000 tons of SO_2, CO_2, and FPM per annum respectively.

2.4.1.3 Other pollutants

Other than particulates, the combustion of coal also produces nitrogen dioxide, polycyclic aromatic hydrocarbons and benzo(a)pyrene, for which there have been no exposure studies in South Africa. As a result, neither the extent to which these pollutants occur, nor their impact on people or their environment can be quantified. They remain a loose link to an impact study such as this.

2.4.2 Indoor air pollution levels

The need to consider indoor air pollution levels is demonstrated by two facts. Firstly, low-income households generally use low-grade coal resulting in high particulate emissions, often under poorly ventilated conditions. This results in small highly polluted environments. Secondly, the Vaal Triangle Air Pollution Health Study (VAPS) of a group of school children aged 8 to 12 years, found that they spent an average of 75% of their time indoors (Terblanche et al 1992b:553), thus placing them in such potentially highly polluted environments for a large portion of the day.

An earlier study conducted by the Council for Scientific and Industrial Research (CSIR) and the Medical Research Council (MRC) in 1991, which measured the personal exposure to pollutants of a group of 45 children aged 8 to 12, living near Sebokeng, showed extremely high exposure to total suspended particulates (TSP's), with the 12 hour levels exceeding the US EPA 24-hour standard of 260μgm^{-3} in 99% of the cases (average was 310μgm^{-3}) (Terblanche et al 1992a: 41-43).

One component of the VAPS study however calls caution to the optimisim of seeing electrification as being the solution that will remove these pollutants. The study examined the exposure levels of children from high and middle-income households that have electricity as their only energy source in areas that were known to be relatively polluted by industrial sources. Still, 63% of exposures exceeded the EPA 24-hour standard. This study indicates that background pollution levels in the areas examined are high, and that gains from electrification will not be sufficient to improve the air quality to an acceptable standard.

2.4.3 Health impacts

There are unfortunately no studies which have calculated the dose-response relationship between exposure to particulate pollution and health impacts. Such impacts have however been inferred from epidemiological studies (Kossove 1982; Zwi et al 1990; Terblanche et al 1992a: 52-53).

Lennon et al (1994) cite Terblanche et al (1992) who found that the current levels of FPM in the study areas 'pose the greatest threat (from air pollution) to health in the region' but that 'current levels of SO_2, although relatively high when compared with other areas, do not represent as major an environmental hazard in the domestic sector as do particulates'.

In the VAPS study, Terblanche et al (1992) found that 65% of 11 000 children suffered upper respiratory illness, and 29% had complaints of lower respiratory illness. They were able to implicate TSP as a cause of this high prevalence.

Van Horen (1996b) attempts to determine the extent of physical health effects from particulate emissions by coal-using households. Using an estimated concentration of 272 gm-3 of fine particulate matter in poor households in conjunction with PM10 dose response functions and an estimated population of 6 million people he estimates the probable occurrence of physical health effects, such as asthma attacks and bronchitis. These estimates are presented in Table 7 below.

Health outcome	*Unit*	*Low estimate*	*Central estimate*	*High estimate*
Athsma attack	Occurrence-day	22032	39168	132192
Acute bronchitis	Occurrence	427950	855899	1283849
Chronic bronchitis	Person	32912	66921	102027
Outpatient/GP visit	Visit	522	1061	1583
Mortality	Death	10	17	24
Resp. Symptom day	Occurrence-day	326400	750720	1142400
Resp. Hospital adm.	Admission	29	54	78
Restricted activity	Occurrence-day	87765	175530	274266

Table 7: Physical health effects resulting from particulate emissions by coal using households
Source: Van Horen (1996: 160)

2.5 Impacts of LPG

Liquefied petroleum gas (LPG) is predominantly a mixture of C_3 and C_4 hydrocarbons with other hydrocarbons in the C_{1-7} range. The main constituents are thus propane or butanes. They are gases at normal ambient temperature and pressure, and are liquefied under pressure to facilitate easier transportation and storage.

The impacts of LPG can be viewed as occurring in five distinct areas, namely:

- at extraction of the raw material;
- with transportation of the raw material to the point of processing;
- at the point of processing/refining;
- with transportation to the consumer;
- at point-of-use.

LPG can be produced in a number of ways:

- as the light end fractions of distillation and cracking processes;
- with the production of crude oil;
- through the purification of natural gas; or
- from coal, as is done with the SASOL processes.

The variety of means by which LPG is produced creates problems for quantification of the impacts associated with the production of LPG as there are not only different types and sources of raw material, but also different 'extraction' processes that require different inputs (including different amounts of energy). The impacts of LPG produced in refining processes is further complicated by a need to apportion the impacts amongst the different products produced in the cracking process. These impacts can, however, not be ignored. The attention that air pollution from refineries is receiving in South Africa (for example, air pollution experienced in the areas surrounding the Durban refineries) suggest that the negative impact of South African refineries can be large, and that the externality cost associated with LPG could also be significant. An assessment of the impact of each processing facility would be a necessary starting point.

The hazards associated with LPG at point-of-use are those of fire, explosion, and asphyxiation. LPG is heavier than air and, if released accidentally, may accumulate in confined and low lying spaces until such time as that it evaporates. It is not a respiratory irritant and brief exposure does not seem to cause any systemic effects. It does, however, have a narcotic effect if inhaled in concentrations over 10%, resulting in weakness, headache, light-headedness, nausea, confusion, blurring of vision, and increasing drowsiness. At high concentrations it can lead to asphyxiation as a result of oxygen deficiency (Concawe 1992).

The Concawe (1992) product dossier, after an extensive literature search, claims not to have been able to identify any reference to ecotoxicological effects of LPG or its primary constituents. They go on to claim that because of their high volatility, LPG's are unlikely to cause ground or water pollution, and that when released into the environment, they will disperse and undergo photochemical degradation.

No studies quantifying the impact of LPG, at point of production, or at point of use in South Africa, were found during the course of the writing of this paper and, therefore, it was not possible to value these impacts.

2.6 Conclusion

The above discussion has detailed a range of potential environmental and social impacts which occur in the extraction, production, transmission and use of the different fuels consumed in low-income households. While a wide range of environmental and social impacts of energy use exist, the availability of information on the different impacts varies significantly and, therefore, the ability to assess the extent and cost of the impacts to society differs. For example, there is substantial quantifiable information available on the electricity sector, while there has been no significant research on the impacts of gas production and use and little information is available on the environmental impacts of the extraction and production of paraffin. Thus, any analysis evaluating the environmental impacts of current energy use or the potential of an energy efficiency intervention to reduce environmental impacts must be treated with caution.

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

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

The valuation of these impacts is detailed in Section 3 below.

3. Assessing the impacts

Van Horen (1996a; 1996b) analyses the above-mentioned impacts providing, for each impact, a range of estimates of both the physical health and environmental outcomes and the external costs of these occurrences. Based on Van Horen's central estimates, Table 8 below presents the physical health outcomes of energy use and Table 9 presents the external cost of energy use in Rands per gigajoule.

Physical health outcomes	*Unit*	*Estimate*
Electricity generation	(per GWh)	
Air pollution	occurrence-day	9.404
Asthma	person	0.046
Acute bronchitis	person	0.007
Chronic bronchitis	visit	0.040
Outpatients	deaths	0.001
Deaths	admission	0.004
Hospital admissions	occurrence-day	36.667
Respiratory symptom days	occurrence-day	6.731
Restricted activity days	(per thousand GWh)	
Coal mining		0.874
Injuries		0.156
Deaths	(litres per kWh)	1.43
Water consumption		
Coal pollution	(per megatonnes coal)	
Asthma	occurrence-day	11 869
Acute bronchitis	person	259 363
Chronic bronchitis	person	20 279
Outpatients	visit	322
Deaths	deaths	5
Hospital admissions	admissions	16
Respiratory symptom days	occurrence-day	227 491
Restricted activity days	occurrence-day	53 191
Paraffin poisoning	(per megalitres paraffin)	
Admissions		15.94
Outpatients		14.71
Deaths		0.4
Paraffin-related burns	(per megalitres paraffin)	
Admissions		11.71
Deaths		0.76

Table 8: Physical impacts of energy use
Source: Adapted from Van Horen (1996a; 1996b)

The external costs presented in Table 9 are calculated using an opportunity cost or 'cost of illness' approach. This methodology takes into account the health effects in terms of the actual expenditure on health care (both public and private), transport costs, and medication, as well as in terms of foregone income resulting from lost time at work. While being the most comprehensive valuation of the health impacts of energy production and use, Van Horen's valuation represents only a partial picture of the costs associated with coal combustion, household use of candles and paraffin, and production of electricity. The values do not reflect the pain, suffering and emotional trauma associated with the illness or disability. In addition, the valuation is restricted by the availability of information. For example, in his evaluation of the impacts of air pollution, Van Horen (1996a; 1996b) was only able to consider the health effects of particulate emissions, and not those of carbon monoxide, sulphur oxides, nitrogen oxides, and ozone.

Where mortality is accounted, the externality cost of each fatality is assumed to range from a lowest value of R851 157 to a highest value of R1 936 101. The central value assumed is R1 260 162 for each fatality. The valuation of a human life is a much debated issue in economics, and a number of methodologies have been suggested to determine such a value. This report cannot go into detail on these debates; it must suffice to acknowledge that there are significant problems (practical and ethical) with such valuations and that values are not neutral, but have social and political weighting. Mortality valuations can, therefore, vary significantly. The valuation method used in this instance was the benefit transfer approach in which international willingness-to-pay valuations were adjusted on the basis of income differentials. This method incorporates a value for the suffering that an individual or their next of kin will undergo in the event of death. Morbidity valuations were on the other hand based on a 'cost of illness' or opportunity cost approach that takes no account of the pain and suffering felt by the ill person or their family.

Energy source	*Externality cost (R/GJ)*
Electricity generation	
Health impacts	1.66
Water consumption	0.35
Coal	3.61
Paraffin	41.25

Table 9: External costs of energy (R/GJ)
Source: Adapted from Van Horen (1996a; 1996b)

4. Strategic interventions

This section illustrates the potential environmental benefits of the proposed programme interventions emerging from the E4 project. The E4 project proposed four broad areas for intervention – fuel-switching, energy-efficient low-cost housing, energy-efficient lighting and energy-efficient appliances. The rationale for the focus on these four areas is presented in a synthesis report by Simmonds and Clark (1998) entitled 'Energy strategies for the urban poor'.

As the reduction in the environmental impacts is linked to the reduction in use of the different forms of energy, we do not present the results for all the proposed interventions, but rather for selected illustrative examples. The interventions included in the analysis are:

- Fuel switching: switching from one fuel/appliance combination to another, such as:
    - paraffin to gas for cooking;
    - electricity to gas for cooking; and
    - paraffin to electricity for lighting.
- Energy-efficient low-cost housing: ceiling installation and passive solar orientation.
- Energy-efficient lighting: switching from incandescent to compact fluorescent lamps.

The work undertaken by Van Horen (1996a; 1996b) is applied to these specific energy efficiency programme interventions to produce a summary of the environmental benefits associated with the potential reduction in energy use resulting from each intervention. Section 4.1 presents the assumptions for these programme interventions and Section 4.2 details the potential environmental benefits of these programmes.

4.1 Programme assumptions

This section calculates the reductions, and where appropriate increases, in fuel consumption resulting from each programme intervention. The programme assumptions are detailed in the description of the methodologies applied to each intervention.

The calorific values presented in Table 10 and the appliance efficiencies presented in Table 11 are applied standardly across all interventions.

Fuel type	*Calorific value*
Electricity	3.6 MJ/kWh
Coal	27 MJ/kilogram
Wood	15.5 MJ/kilogram
Paraffin	38 MJ/litre
Gas	49.8 MJ/kilogram

Table 10: Calorific value of different fuel types
Source: Davis (1999)

Appliance	*Efficiency*
Cooking	
Paraffin wick stove	28%
Gas ring	50%
Electric hot plate	65%
Lighting	
Paraffin wick	330 lumen hours/MJ
Incandescent bulb	3 000 lumen hours/MJ

Table 11: Appliance efficiencies
Source: Fecher (1998)

4.1.1 Fuel switching

4.1.1.1 Switch from paraffin

Two switches from paraffin are analysed – to gas for cooking and to electricity for lighting. Although some fuel switching may occur with the construction of new housing and electrification, previous studies have shown that fuel switching generally occurs gradually. As there are no well developed fuel switching strategies, either in Eskom or the DME, and limited analysis on the rate at which people might switch, assumptions are required regarding the share of households which will switch and rate at which they will do so. The assumptions are based on two principles – half of the households would switch by the end of 10 years and these switches would occur gradually over the 10 years (Fecher 1998).

Given that approximately 924 529 low-income urban households are currently using paraffin, 462 265 households will convert from paraffin over the programme duration (Fecher 1998). Assuming that the programme intervention takes place over 10 years, the conversion from paraffin to other fuels will take place at a rate of 46 226 households per annum. The energy shifts and associated environmental impacts for the two programme interventions are calculated over a period of 20 years.

4.1.1.1.1 Paraffin to gas for cooking

Davis (1999) calculates that given appliance efficiencies of 30% and 50% for a paraffin wick stove and gas ring respectively, the daily energy use for a paraffin wick stove is 0.6 litres of paraffin and the daily energy use of a gas ring is approximately 0.27 kilograms of gas. This amounts to an annual energy use of 219 litres (8 322MJ) of paraffin and 103 kilograms (5 124MJ) of gas to meet household cooking needs.

Assuming the installation of 46 226 gas rings in place of paraffin wick stoves per annum for 10 years, there will be a decrease in paraffin use of 1 569 megalitres and an increase in gas use of 737 kilo tonnes.

4.1.1.1.2 Paraffin to electricity for lighting

Fecher (1998) calculates that, given an annual lighting use of 1 368.8 thousand lumen hours, and a delivered energy use of approximately 3 MJ and 0.3 MJ per thousand lumen hours for a paraffin pressure lamp and an incandescent bulb respectively; the annual fuel use for a single household will be approximately 4 106.3 MJ for paraffin lighting and 448 MJ for electric incandescent lighting of equivalent output.

Assuming the replacement of 46 226 paraffin pressure lamps with electric incandescent lighting per annum for 10 years, there will be a decrease in paraffin use of 774 megalitres and an increase in electricity use of 892 GWh.

4.1.1.2 Electricity to gas for cooking

Outside of the rural areas, there are no institutions currently promoting the use of gas for cooking. An assumption is, therefore, made that over a period of 10 years, one million gas cookers could be installed in low-income households replacing current and future use of electricity for cooking.

4.1.1.2.1 Household model

The household model calculates the energy savings based on the relative efficiencies of the two appliance/fuel combinations. Assuming that households cook for 2.5 hours per day and that an electric hot plate consumes 1.2 kW of power, the average annual electricity use is 1 095 kWh (3 942MJ).

Given appliance efficiencies of 65% for an electric hot plate and 50% for a gas ring, it is calculated that a gas ring will use approximately 0.11 kilograms of gas per hour. The average annual consumption of gas for cooking is, therefore, 103 kilograms (5 129MJ).

4.1.1.2.2 Programme energy savings

The energy shifts resulting from the gas cooker programme are calculated over a period of 20 years. Assuming a per annum replacement of 100 000 electric hot plates with gas rings for the first 10 years, the programme intervention will result in a reduction in electricity use of 16 973 GWh and an increase in gas use of approximately 1 595 kilo tonnes.

4.1.2 Energy-efficient low-cost housing

The South African government committed themselves, as part of the Reconstruction and Development Programme, to constructing one million new low-cost houses over a period of five years. Considering the substantial short fall in low-cost housing in South Africa, we can assume that the national housing programme will be continued in future election periods. Assuming the construction of 100 000 houses per annum over a period of 20 years, a total of two million new houses could be constructed.

4.1.2.1 Household model

Currently, few developers involved in the delivery of low-cost housing pay attention to passive solar design. Most low-cost houses do not include ceilings and exhibit very poor thermal performance. Research and practical experience has shown that through the addition of a ceiling and other no- and low-cost passive design measures, such as correct orientation and placement of windows, between 50% and 70% of the household space-heating bill can be saved.

Assuming that the space-heating requirement for a standard house, without a ceiling and other passive solar design features, is 2 268MJ per annum and that 60% of that space-heating bill can be saved through the addition of a ceiling and other low- and no-cost measures, the average annual energy saving per household will be approximately 1 361MJ.

A range of fuels – electricity, coal, wood, paraffin and gas – are used by low-income households to meet space-heating requirements. Constructing a household model of energy savings, therefore, requires an assumption about the energy consumption patterns for space-heating.

Table 12 below presents the share of low-income households using the different space-heating fuels. These figures are derived from Eskom's (1996) residential survey of consumption patterns in urban informal and township (low-income formal) houses and adjusted to take into account a shift toward electricity over time.

Fuel source	*Share of houses*
Electricity	38%
Coal	15%
Wood	9%
Paraffin	22%
Gas	2%
TOTAL	**86%**

Table 12: Proportion of households using different space-heating fuels

To develop a single household model, a theoretical 'average house' was calculated using the weighted average of energy savings across all types. The annual energy savings for the average household are presented in Table 13.

Fuel type	*Unit*	*Annual energy saving*
Electricity	kWh	165.6
Coal	kg	8.4
Wood	kg	9.6
Paraffin	litre	9.6
Gas	kg	1.2

Table 13: Annual energy savings for average household

4.1.2.2 Programme energy savings

The programme energy savings are calculated over a period of 40 years. Table 14 presents the programme energy savings by fuel type, assuming the installation of 100 000 ceilings per annum over a period of 20 years.

Fuel type	*Unit*	*Programme savings*
Electricity	GWh	10 101.6
Coal	kilo tonnes	512.4
Wood	kilo tonnes	585.6
Paraffin	megalitres	585.6
Gas	kilo tonnes	73.2

Table 14: Energy-efficient housing programme energy savings

4.1.3 Energy-efficient lighting

Eskom is currently embarking on an energy-efficient lighting programme. The energy-efficient lighting programme aims to replace 60W incandescent light bulbs with 15W compact fluorescent lamps (CFLs), installing a total of 9 684 000 CFLs over a period of 20 years.

4.1.3.1 Household model

The annual energy savings from a single bulb can be expressed as:

> Annual energy savings = ((Wi – Wcfl) x annual hours) – ((Wi – Wcfl) x annual hours x take-back effect), where
>
> Wi = Wattage of incandescent

Wcfl = Wattage of CFL

Given a daily usage for a single bulb of 3.2 hours, the annual usage is 1 168 hours. As a 15W CFL is assumed to replace a 60W incandescent, and the take-back effect is assumed to be approximately 25% of energy saved, the annual energy savings for a single bulb would be:

(45W x 1 168) – (45W x 1 168 x 0.25) = 39.42 kWh (142MJ)

4.1.3.2 Programme energy savings
The CFLs are assumed to have a life of 8 000 hours. Assuming that 9 684 000 CFLs are distributed over a period of 20 years as presented in Table 15 below, and that each CFL distributed through the programme is replaced by the household when it reaches the end of its life, the total programme energy savings over a period of 40 years will be 10 991 GWh.

Year	*CFLs*
1	30 000
2	110 000
3	192 000
4	274 000
5	352 000
6	430 000
7	508 000
8	583 000
9	617 000
10	613 000
11-15	620 000
16-20	575 000
Total	9 684 000

Table 15: Distribution of CFLs per annum

4.2 Potential environmental benefits

4.2.1 Fuel switching

4.2.1.1 Switch from paraffin
Table 16 below summarises the environmental impacts resulting from a switch away from paraffin and toward gas for cooking and electricity for lighting. The results show that any shift away from paraffin will provide substantial environmental benefits. It should be noted, however, that for the switch from paraffin to gas for cooking, there is insufficient information to determine the potential environmental impacts of an increase in gas use. The clean-burning qualities of gas at point-of-use do, however, suggest that the environmental health benefits resulting from a decrease in paraffin use will far outweigh the potential environmental health impacts from an increase in gas use.

	Paraffin to gas for cooking	*Paraffin to electricity for lighting*	
	Paraffin (decrease)	Paraffin (decrease)	Electricity (increase)
Poisonings			
Hospitalisation (no of cases)	25 021	12 342	
Outpatients (no of cases)	23 082	11 389	
Deaths	628	310	
Fires and burns			
Hospitalisation	18 375	9 067	
Deaths	1 193	588	
Health impacts of air pollution			
Asthma Attacks (occurrence-day)			8 384
Acute bronchitis (no of people)			41
Chronic bronchitis (no of people)			6
Outpatient/GP visit (visits)			36
Deaths (no of people)			1
Hospitalisation (admission)			4
Respiratory Symptom Day (occurrence-day)			32 691
Restricted activity (occurrence day)			6 001
Mining fatalities and injuries			
Injuries			1
Deaths			0
Water consumption (Megalitres)			1 275

Table 16: Environmental impacts of switch from paraffin to gas for cooking and to electricity for lighting

Applying the external cost estimates from Table 9 to the switch from paraffin to electricity for lighting, the present value of the reduction in health costs is approximately R539 million from the paraffin energy savings and the present value of the increase in health costs is approximately R2 million from the additional electricity used. The programme thus provides a net environmental cost benefit of R537 million. For the switch from paraffin to gas for cooking, the present value of the reduction in health costs related to reduced paraffin use is approximately R1 092 million.

4.2.1.2 Electricity to gas for cooking

When evaluating the total environmental benefit of the a switch from electricity to gas for cooking, at best we can show the environmental benefits of a reduction in electricity use (Table 17). The analysis cannot demonstrate the total benefit of the programme as there is insufficient information to evaluate the environmental impacts of gas.

	Electricity to gas for cooking
PROGRAMME ENERGY SAVINGS	16 973 GWh
Health impacts of air pollution	
Asthma Attacks (occurrence-day)	159 602
Acute bronchitis (no of people)	787
Chronic bronchitis (no of people)	120
Outpatient/GP visit (visits)	686
Deaths (no of people)	20
Hospitalisation (admission)	76
Respiratory Symptom Day (occurrence-day)	622 339
Restricted activity (occurrence day)	114 242
Mining fatalities and injuries	
Injuries	15
Deaths	3
Water consumption (Megalitres)	24 270

Table 17: Reduction in environmental impacts associated with the gas cooker programme

Applying the external cost estimates from Table 9 to the electricity savings resulting from the intervention, indicates a potential saving in health costs of approximately R45 million (1994 Rands).

4.2.2 Energy-efficient housing

Improved thermal efficiency reduces the amount of fuel required for space heating and, therefore, reduces the level of exposure to particulates. Furthermore, the reduction in demand for fuel will reduce the risks associated both with using the fuel in the household and with exploiting the energy source. Table 18 below shows the potential environmental benefits resulting from the intervention.

	Paraffin	*Coal*	*Wood*	*Electricity*
PROGRAMME ENERGY SAVINGS	585.6 megalitres	512 400 tonnes	585 600 tonnes	10 101.6 GWh
Poisonings				
Hospitalisation (no of cases)	9 334			
Outpatients (no of cases)	8 614			
Deaths	234			
Fires and burns				
Hospitalisation	6 857			
Deaths	445			
Health impacts of air pollution				
Asthma Attacks (occurrence-day)		6 082	20 023	94 991
Acute bronchitis (no of people)		132 898	437 546	468
Chronic bronchitis (no of people)		10 391	34 211	72
Outpatient/GP visit (visits)		165	542	409
Deaths (no of people)		3	8	12
Hospitalisation (admission)		8	28	45
Respiratory Symptom Day (occurrence-day)		116 566	383 777	370 400
Restricted activity (occurrence day)		27 255	89 733	67 994
Mining fatalities and injuries				
Injuries				9
Deaths				2
Water consumption (Megalitres)				7 064

Table 18: Reduction of environmental impacts of thermally efficient housing programme

Over a 40-year period, the two million ceilings installed in low-cost houses will reap substantial environmental benefits. With only 22% (440 000 houses) of the two million houses targeted by the programme using paraffin for space-heating, 679 deaths, 6 857 burns admissions and 9 334 poisoning admissions could be avoided in paraffin-using households alone. Applying the external cost estimates from Table 9 to the total programme energy savings over the 40-year period reveals a potential saving in health costs of approximately R222 million (1994 Rands)

4.2.3 Energy-efficient lighting

The shift toward more efficient electrical lighting in the CFL programme results in an electricity saving of 10 911 GWh over a 40-year period. While this saving in electricity represents lost revenue to the utility, it has direct environmental benefits in the reduction of air pollution and its associated health impacts; the reduction of coal consumption with its associated mining injuries and deaths; and the reduction of water consumption, a commodity which is scarce in South Africa. With the installation of approximately 9.7 million CFLs, 13 respiratory-related deaths and 49 respiratory-related hospital admissions could be avoided (Table 19).

	CFL
PROGRAMME ENERGY SAVINGS	10 991 GWh
Health impacts of air pollution	
Asthma Attacks (occurrence-day)	103 359
Acute bronchitis (no of people)	509
Chronic bronchitis (no of people)	78
Outpatient/GP visit (visits)	445
Deaths (no of people)	13
Hospitalisation (admission)	49
Respiratory Symptom Day (occurrence-day)	403 028
Restricted activity (occurrence day)	73 983
Mining fatalities and injuries	
Injuries	10
Deaths	2
Water consumption (Megalitres)	15 717 Ml

Table 19: Reduction in environmental impacts associated with the CFL programme

Applying the external cost estimates from Table 9 to the electricity savings of the CFL programme, the present value of the health costs in 1994 Rands is approximately R13 million.

4.3 Cost summary

Table 20 provides a summary of the programme savings in health costs. It should be noted that, for the switches to gas, only a partial picture of the programme's environmental cost savings are presented. These reductions in health costs for the programme do not include the potential environmental health costs associated with an increase in gas use and, therefore, may be over-estimated.

Programme intervention	*Health cost saving (R million)*
Fuel switching	
From paraffin to gas for cooking	1 092
From paraffin to electricity for lighting	537
From electricity to gas for cooking	45
Energy-efficient housing	222
Energy-efficient lighting	13

Table 20: Present value of the programme cost savings for selected interventions (1994 Rands)

5. Conclusions

While the calculations predicting the change in the incidence of impacts such as paraffin poisoning or mortality as a result of fire can be made with relative confidence, the same cannot be said for the calculations concerning the change in impact that results from a change in demand for electricity, even if it assumed that any increase in demand would occur at peak periods, and would therefore effect 'new' generation. This is firstly due to the nature of coal fired electricity generation. A change in demand does not necessarily translate into an equivalent change in production (demand can increase smoothly, or in small steps, but producers are restricted in the minimum size of the increases they can make at any one time). The relationship between the increased demand for electricity, and production of air pollutants is thus not a linear one. Secondly, the dose-response relationships that the human body has for air pollutants can not be considered to be linear. The derivation of a unit impact per amount of electricity generated however assumes such a relationship. The figures presented for the change in air pollution related impacts can therefore only be viewed as very rough estimates. It should be noted however that such inaccuracies are included (and hidden) within any calculation that uses *unit* externality costs (as done above) to determine the extent of any change in the *overall* externality cost. The theoretically more appropriate solution to the problems of predicting the potential change in externalities associated with increased electricity production would be a localised analysis (for the region where the new capacity is generated). Such an analysis would have to model the change in pollutant emissions and their dispersion, to determine the new ambient pollution levels for that region, and determined via a dose response relationship what the new extent of the impacts would be. The extent of any change in impacts would then be determined by comparing projected and existing levels of impact.

Taking this into consideration, the examples presented in Section 4.2 illustrate that significant environmental benefits can be achieved through energy efficiency interventions in low-income households. Where there is a switch away from paraffin or a reduction in paraffin use, this is particularly true. The local environmental impacts of paraffin are shown to be significant for low-income households and, therefore, programmes which either reduce paraffin use (such as the interventions discussed in this report) or increase paraffin safety should be a national priority.

References

Annegarn H and Keen, M 1994. Source apportionment of Township air pollution, Draft final report DMEA project EF 94 08, DMEA.

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

Central Statistical Services 1997. Wholesale trade of petroleum products, December 1996. Central Statistical Services. Pretoria.

CONCAWE 1992. Liquefied petroleum gas, product dossier no. 92/102. CONCAWE petroleum products and health management group, Brussels.

Cowan, W 1992. Global warming and energy scenarios for developing areas of South Africa. Energy and Development Research Centre. University of Cape Town.

Davis, M 1999. Personal communication.

Dei, C 1997. A proposal for a workshop on improving indoor air quality in low income South African households.

DWAF 1991. Water quality management policies and strategies in the RSA. Department of Water Affairs and Forestry. Pretoria.

Ellis, J, Krug, A, Robertson, J, Hay, I and MacIntyre, U 1994. Paraffin ingestion – the problem. *South African Medical Journal*. Vol. 84. No 11.

Eskom 1995. Eskom environmental report 1994. Eskom: Johannesburg.

Eskom 1996. IEP5

Eskom 1996. Statistical Yearbook. Eskom: Sandton.

Fecher, R 1998. The real cost of conserving energy. Energy and Development Research Centre, University of Cape Town.

Freeman, M, Kolberg, M, Bendow, M, Guy, D, Johnson, W and Abron, L 1997. Carbon monoxide testing of Kutlwanong community Northern Cape "Shackdwellers", a project under the US/RSA Gore-Mbeki Binational Commission (BNC) sponsored by US AID/PEER Africa (Pty.) Ltd.

Gerson, R 1992. The environmental effects of air pollution from the energy sector in South Africa. Msc thesis Energy and Development Research Centre, University of Cape Town.

Kossove, D 1982. Smoke filled rooms and lower respiratory disease in infants. South African Medical Journal. Vol 61.

Lennon, S, Tosen, G, Morris, M, Turner, C & Terblanche, P 1994. Synthesis report on the environmental impacts of electrification. Report for the National Electrification Forum. Report No WGEU05.

Lennon, S and Turner, C 1992. Air quality impacts in South Africa: addressing common misconceptions. *Journal of Energy Research and Development in Southern Africa*. May 1992.

Lerer, L 1995. Review of the biomedical literature relating to energy and health. Medical Research Council. Cape Town.

Mehlwana, M 1998. The anatomy of a disaster: Case studies of health and safety aspects of fuel use in poor communities. Paper presented at the *Workshop on Identifying Avenues of Intervention on Indoor Air Quality in Low-Income South African Households*, March 19-20, 1998. Pretoria.Naidoo, S 1997. Eskom, Johannesburg. Personal comment.

Palmer Development Group 1995. The potential market for low smoke coal. Draft report for the Department of Mineral and Energy Affairs. Pretoria.

Piketh, S and Annegarn, H 1994. Dry deposition of sulphate aerosols and acid rain potential in the Eastern Transvaal and Lowveld regions. National Association for Clean Air Conference. Cape Town.

Pillay, Y 1997. Personal communication. Eskom, Johannesburg.

Praetorius, B and Fecher, R 1998. Greenhouse gas impacts of DSM: Emission reduction through energy efficiency interventions in low-income urban households. Energy and Development Research Centre, University of Cape Town.

Raimondo, J, Van Zyl, H, Bonner, D and Brownlie, S 1995. Environmental cost internalisation in the South African coal mining industry. Draft report for UNCTAD. Cape Town.

Roberts, J, Leary, P, Mann, M and Gladstone, M 1990. The pattern of childhood poisoning in the Western Cape. *South African Medical Journal*. Vol. 78. No. 7.

Scholand, M 1997. Indoor Air Quality: Health effects and remedial interventions. A case study of South Africa. Unpublished Masters Thesis submitted; to Tufts University.

Scholes, R and van der Merwe, M 1995. South African greenhouse gas inventory. CSIR report for the Department of Environment Affairs and Tourism. Council for Scientific and Industrial Research, Pretoria. Report FOR DEA-918.

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

Simmonds, G 1997a. Barriers to energy-efficient low-cost housing. Energy and Development Research Centre, University of Cape Town.

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

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

Sithole, J, Turner, C, Lynch, E, Rorich, R and Annegarn, H 1991. Air pollution exposures in coal burning residential areas of South Africa. National Association of Clean Air. Durban.

Terblanche, P, Nel, C and Opperman, L 1992a. Health and safety aspects of domestic fuels. Report to the National Energy Council. Medical Research Council. Pretoria.

Terblanche, P, Opperman, L, Nel, C, Reinach, S, Tosen, G and Cadman, A 1992b. Preliminary results of exposure measurements and health effects of the Vaal Triangle Air Pollution Study. *South African Medical Journal.* Vol 81.

Terblanche, P, Nel, R and Golding, A 1994. Household energy sources in South Africa – an overview of the impact of air pollution on human health. CSIR Environmental Services, Department of Mineral and Energy Affairs and EMS, Pretoria.

Terblanche, P and Pols, A 1994. Characterisation of risk factors associated with household fuel usage in South Africa. Report for the Department of Mineral and Energy Affairs, Project No EO 9308.

The Institution of Electrical Engineers, 1994. The possible biological effects of low-frequency electromagnetic fields. Supplement to the public affairs board report, June 1994.

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

Tosen, G, Turner, C and Terblanche, P 1991. Outdoor air pollution monitoring – the first years of VAPS. National Association of Clean Air. Durban.

Turner, C, Tosen, G, Lennon, S and Blackbeard, P 1990. Eskoms air quality impacts – a regional perspective. World Energy Council Forum. Harare.

Turner, C 1994. Visibility impairment in the rural Eastern Transvaal Highveld region, Eskom Technology Group report No. TRR/S94/164/rw.

Tyson, P, Kruger, F and Louw, C 1988. Atmospheric pollution and its implications in the Eastern Transvaal Highveld. South African National Scientific Programmes. Report no. 150. Pretoria.

Van Horen, C and Simmonds, G 1995. Greenhouse gas abatement in South Africa's energy sector. Paper presented at the Regional Workshop on greenhouse gas mitigation for African countries. Arusha, Tanzania. 28 – 30 August 1995.

Van Horen, C 1996. The cost of power: externalities in South Africas energy sector. Doctoral dissertation. University of Cape Town.

Van Rensberg, D 1994. Environmental contributions to atmospheric corrosion (3rd year). Report no. TRR/S94/194/djvr. Eskom TRI. Johannesburg.

Yach, D 1994. Editorial: Paraffin poisoning – partnership the key to prevention. *South African Medical Journal.* Vol. 84. No. 11.

Zwi, S, Davies, J, Becklake, M, Goldman, H, Reinach, S and Kallenbach, J 1990. Respiratory health status of children in the Eastern Transvaal Highveld. *South African Medical Journal.* Vol.78.