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**An**  
**Economic and Financial Evaluation**  
**of the**  
**Health Benefits of Electrification**

**by Jaco Delport**

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# Abstract

The health benefits of a national household electrification programme are investigated. Cognisance is taken of the lack of utilisation of electricity by newly electrified households. The impact of electrification on air pollution levels and paraffin utilisation is investigated to establish the effect on morbidity due to respiratory infection, paraffin poisoning and burns. The reduced demand for health services stemming from a reduction in morbidity is quantified and its macroeconomic implications investigated. The implications that the results of this quantification process holds for the financing requirements of a national household electrification programme as well as the microeconomic factors underlying the success of such a programme are highlighted.

Chapter 1 outlines the methodology that will be used to firstly establish the expected switch to electricity as sole energy-carrier by newly electrified households, secondly to establish the health implications of such a switch, and thirdly to quantify these health implications. Chapter 2 reports the results of the modelling exercise, chapter 3 the resulting health implications and chapter 4 the quantification process. Chapter 5 looks at the macroeconomic implications of the health benefits of electrification. Chapter 6 investigates the impact of the results of this thesis on the financing requirements of the electrification programme.

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# Introduction

Approximately 60% of the 7.5 million South African households(HH's) currently do not have access to electricity (EDRC,1993). This shows very clearly the ravages of the apartheid years due to the fact that the 60% referred to above are almost exclusively black, coloured and Asian HH's, and also highlights the extreme inequality in access to basic prerequisites for healthy and productive living currently prevalent in South Africa. Eskom, under the coordination of the National Electrification Forum (NELF), has undertaken to attempt to address this problem through an extensive national HH electrification programme, the details of which are highlighted in this thesis.

Such a widespread electrification programme will have a major impact on the socio-economic environment of all the people of South Africa. Electricity provision not only implies access to adequate lighting, heating and cooking facilities but also has social implications such as improved educational facilities, refrigeration, entertainment, and so on. It further implies an overall improvement in the health status of the currently non-electrified HH's due to the comparatively environmentally friendly nature of electricity as an energy-carrier. This thesis attempts to investigate these health benefits of electrification.

This task is complicated by the fact that electricity provision does not imply electricity use. One of the main reasons for the slow pace of electrification in the past and in the future is a lack of funding which stems primarily from the non-viable level of electricity utilisation by newly electrified HH's. This thesis therefore attempts to model expected electricity use in a totally electrified situation. The behaviour of previously electrified HH's is used as a model for the behaviour of newly electrified HH's to establish the extent to which newly electrified HH's will switch to electricity as their sole energy-carrier.

A review of biomedical literature reveals that the most significant health impact of electrification will result from three areas. Firstly, reduced use of 'dirty' fuels such as coal, wood and paraffin will lead to a reduction in air pollution levels which in turn lead to a decrease in morbidity due to respiratory infections. Secondly, reduced use of paraffin results in fewer paraffin poisoning cases, and thirdly, increased use of electricity leads to a reduced number of burns. Given the expected percentage switch to electricity as sole energy-carrier it is possible to calculate the impact of this switch on air pollution levels and paraffin utilisation as well as the resulting impact on respiratory infection, paraffin poisoning and burn morbidity.

The electricity-associated reduction in morbidity in turn generates a reduced demand for health services. The second objective of this thesis is to calculate the economic saving to the South African economy that results from the health impact of electrification. This is done by quantifying in monetary terms the reduced demand for health services.

The economic saving thus calculated has certain macroeconomic repercussions. These are also investigated so as to establish the impact of the health benefits of electrification at a macroeconomic level.

At the outset the lack of funding for the electrification programme was noted. The economic saving generated in the health sector of the economy as mentioned above can directly be attributed to the production of electricity and can thus be seen as the revenue income of the second stage of a two-stage electricity production function. This future income stream is included in the current estimates of the financing requirements of the electrification programme to investigate the financial viability of electrification as a health intervention.

There is very little doubt that by investigating the health benefits of electrification a very strong ethical case can be made for a widespread HH electrification programme. However, the harsh reality of the economic problem in terms of unlimited needs and limited resources, is nowhere more clear than amongst the apartheid sufferers of South Africa. This includes far more than merely a lack of access to electricity. With a national budget already stretched to the limit, efficient allocation of resources is of the utmost importance. It is for this reason that the health benefits of electrification must be quantified and evaluated from both an economic and a financial perspective. It helps to paint the whole electrification picture, and enables policy makers to make an informed decision about the viability of the electrification project.

# Chapter 1. Methodology

The methodological framework which will be adopted is outlined in this chapter.

## 1.1. Modelling expected electricity use.

The first component of the methodology involves an attempt to predict the extent to which newly electrified HH's will switch to electricity as their sole energy-carrier once they have access to electricity.

One way of establishing the extent to which newly electrified HH's will switch to electricity for all their HH needs is to analyze the microeconomic intricacies of the decision process that consumers will implement when deciding to use electricity or not. This implies a detailed microeconomic study of consumer behaviour. It entails looking at the substitutability of electricity for current fuels as well as the relative costs, and perhaps more importantly, the effect of the alternative energy-carrier on real income levels. This should shed light on the degree to which typical consumers will substitute electricity for other fuels currently in use. While this will be the most accurate study, it is fraught with difficulties, the most important of which is a lack of data. Not only are both price and income data quite scarce and inaccurate, but the study of the inherent substitutability of electricity for other fuels will require heroic assumptions. One can expect this method to be prohibitively difficult at this stage, given the timeframe of this study. Furthermore, studies such as Eckert et al(1993) have attempted to conduct such analyses. Data problems as well as the extreme variation in energy prices from region to region led them to conclude that very few results hold at an aggregate level, and that this approach therefore becomes ineffective as a predictive tool. Another approach outlined below will therefore be followed for predictive purposes. However, the microeconomic determinants of the outcome of the electrification programme are highlighted in Appendix C of this thesis for clarification purposes.

The alternative is to use a macroeconomic approach, which involves a process of observation and extrapolation. The method used to establish the extent to which provision of electricity will lead to an improved environment is primarily based upon an analysis of the extent to which electricity *provision* will lead to electricity *use*.

It is by no means an accepted fact that once electricity is made available to currently non-electrified groups, a total cessation of the use of alternative energy-carriers such as coal, wood and paraffin would occur. Overwhelming proof of this is the fact that amongst the currently electrified groups in South Africa, a significant number are still using other fuels (EDRC Epret database,1993). Deducing the extent to which non-electrified HH's will utilise electricity when it is provided must take this into account.

This modelling technique assumes that non-electrified and electrified HH's are perfectly comparable. The currently electrified HH's are analyzed and an attempt is made to establish the number of electrified HH's still using alternative fuels. This analysis is complicated by the lack of suitable data. Ideally the following data should be available:

1. The number of electrified HH's.
2. A detailed breakdown of fuel use among the electrified HH's, including specific end- uses, eg. cooking, heating, etc.

This data is only available to a limited extent for certain regions (see Table 1). Where data is available it is used to establish the percentage of previously electrified HH's still using alternative fuels such as coal, wood and paraffin. However, the more likely scenario is that data will be rather sparse.

Very detailed information is available on the average monthly energy consumption patterns (measured in delivered mega-joules/month) of typical electrified and non-electrified HH's in several urban and rural areas of South Africa (EDRC,1993). This information is stratified according to six domestic fuels in use, namely coal, LPG, paraffin, candles, wood and electricity. In the absence of information about the number or percentage of electrified HH's still using alternative fuels, this information is used as a proxy. In other words, it will be assumed that the percentage of total energy consumption provided by any alternative fuel in a typical electrified HH can be used as a proxy for the number of electrified HH's still using alternative fuels.

The rate of substitution thus estimated for previously electrified HH's is applied to the currently non-electrified HH's and results in a prediction about the number of non-electrified HH's that can be expected to switch to electricity as their sole energy-carrier once they are also provided with access to it. The implicit assumption that the socio-economic environment of the previously electrified and currently non-electrified HH's are exactly the same, leads to the conclusion that, if the currently non-electrified HH's were to be electrified, they will behave in exactly the same way as the currently electrified group did when they were electrified.

The fraction of electrified HH's that have switched to total electricity use will be denoted by  $S$ , where  $0 < S < 1$ . If  $NE$  and  $E$  denotes respectively the total number of non-electrified HH's and electrified HH's in the group being analyzed, then:

$$\begin{aligned}(1-S) \times E &= \text{Total number of currently electrified HH's still using alternative fuels.} \\ S \times NE &= \text{Total number of non-electrified HH's expected to use electricity only.}\end{aligned}$$

Having applied this methodology a very rough proxy of the fraction(S) of currently non-electrified HH's expected to switch to electricity as their sole energy-carrier once they are electrified would have been obtained.

Very few HH's in the rural areas of South Africa have been electrified, which results in a problem of selecting an appropriate substitute model to predict the degree to which currently non-electrified rural HH's will switch to electricity as their sole energy-carrier once electrified. A clear definition of what is regarded as urban and what as rural will not only assist in this selection process, but will also increase the accuracy of the predicted substitution that will occur. This is due to the fact that rural HH's in one area are more likely to behave similarly to rural HH's in another area, than urban HH's in another area.

The Energy for Development Research Centre (EDRC,1993) at the University of Cape Town, on whose database this thesis relies extensively, defines the rural poor as farmworkers and their families and rural HH's in the homelands, outside proclaimed towns, residing in dense and scattered settlements who earn less than R850 per month. The rest of South African HH's are classified as urban. Eskom distinguishes between urban and remote areas, but more importantly, between 'remote dense' and 'remote scattered' areas. Both urban and remote densely populated areas have been targeted for electrification within the next 10 years. However, remote scattered areas, which comprise approximately 10% of all HH's in SA, will most likely have to rely on alternative types of fuel. The Development Bank of South Africa supports Graaf's (1986) definition. He distinguishes between official urban areas, which are mainly proclaimed towns, peri-urban areas, which are areas dependent on proclaimed towns, and semi-urban areas, which are denser settlements of 5000 or more people. These three together are referred to as functional urban areas. The rest of South Africa is divided into white rural areas and the homeland areas. To find commonality between these definitions is very difficult and also highly controversial.

This thesis is only concerned with the so-called poorer areas of South Africa, which essentially means the non-white areas, since white areas are already for all practical purposes fully electrified. The only sufficiently detailed energy consumption data for these poorer areas are for the major metropolitan areas, namely the PWV, Cape Town, the Durban Functional Region (DFR) and Pietermaritzburg, and Port Elizabeth (PE) and East London (EL). Less detailed data exist for what the EDRC classifies as secondary urban areas, namely Kimberley and the Orange Freestate (OFS). Data on these areas include data for electrified HH's since small sections of each of these areas have already been electrified.

The only other data available are for the "homelands/self-governing states" of South Africa (see Table 8 for details of what is meant by this area classification) and for farmworkers. However, none of these latter areas contain any previously electrified HH's. If it is accepted that the homelands and farmworkers must be classified as rural, the problem becomes simply a matter of deciding which of the other areas for which data

on previously electrified HH's exist should also be classified as rural to enable it to be used as an acceptable model of behaviour for the non-electrified HH's in the homelands and for farmworker HH's.

As far as the individual HH is concerned, the following factors will determine whether it switches to electricity or not:

- i. which fuel currently supplies most of its energy needs;
- ii. whether electricity will be a good substitute for the fuel currently in use;
- iii. the price of the fuel;
- iv. the price of electricity.

When applying the modelling methodology outlined above to an area where both electrified and non-electrified HH's exist side-by-side, the assumption that two people staying next to each other share the same socio-economic environment can be made. If both are provided with electricity, they can be expected to behave in the same way. However, this assumption becomes less obvious when comparing two HH's in different areas of South Africa. To ensure comparability, it is necessary to analyze this socio-economic environment in more detail.

As will be seen when analyzing the rural data in more detail, wood dominates as energy-carrier in the homelands and for farmworkers. For an area to be used as a model for the expected behaviour in the homelands and for farmworkers, the characteristics of the substitutability of electricity for wood in the homelands should be the same as the characteristics of the substitutability of electricity for whatever alternative fuel dominates in the model area. Furthermore, the relative difference between the price of wood and the price of electricity must be the same as the relative difference between the price of electricity and the price of the dominant alternative fuel in the model area. With both these factors satisfied, the model will approximate the behaviour of the homelands and farmworker HH's.

Based on this analysis, it is clear that the major metropolitan areas must be disqualified as model areas for the homelands and farmworker HH's for a number of reasons. The main reason is that due to the already established infrastructure in the metropolitan areas, electricity should be supplied at a far lower cost than in the homelands. Furthermore, due to the low opportunity cost of labour in the homelands, wood is obtained at a very low cost, thus widening the relative cost difference between the homelands and the metropolitan areas even further.

The only other contenders to model the rural areas for which detailed enough data exists are the two remaining areas classified as secondary urban areas by the EDRC, namely Kimberley and the OFS. An analysis of the non-electrified HH's in these two areas reveal that coal dominates as energy-carrier in the

OFS, while coal, paraffin and wood share the role of energy-carrier in Kimberley. As will be seen later on, coal-stoves present a significant capital barrier to electricity substitution, a barrier which is not present when using wood as energy-carrier. This disqualifies the OFS as a good model for the homelands.

Kimberley has more than the utilisation of wood as energy-carrier in common with the homelands. Both Kimberley and the homelands are characterised by multiple fuel use HH's. While this by no means establishes Kimberley as a perfect model for the homelands, it is the best available model. Kimberley is therefore reclassified as a rural area and will be used as a model for the other rural areas, namely the homelands and the farmworker HH's.

## **1.2. The impact of electrification on health.**

The second component of the methodology shown in figure 1 involves taking the results of the modelling exercise outlined above, and translating them into health benefits. Increased use of electricity or similarly, reduced use of 'dirty' HH fuels such as coal, wood and paraffin should lead to an improved environment. A review of biomedical literature establishes the direct health benefits which will result from this improved environment.

The health benefits of electrification can be divided into direct and indirect benefits. This thesis concentrates on the direct benefits simply because it lends itself more to quantification than do the indirect benefits.

There are three main categories of direct health benefits that may be expected to occur due to electrification<sup>1</sup>. They are, firstly, the health benefits that result from reduced air pollution levels due to reduced utilisation of 'dirty' fuels such as coal and wood. Secondly, reduced levels of paraffin utilisation will be accompanied primarily by reduced cases of paraffin poisoning, but also by a similar but significantly smaller reduction in air pollution levels. Thirdly, a decrease in the number of burn victims may also be expected.

### **1.2.1 Reduced air pollution and health**

It is commonly accepted that the main health benefit of reduced air pollution levels is a reduced incidence of acute respiratory infections (ARI's) (Von Schirnding, Yach & Klein, 1991). This includes both upper respiratory tract infections (URI's), defined as a running nose, earache, hay fever, sinusitis and/or rhinitis, and lower respiratory tract infections (LRI's) defined as chronic bronchitis, chronic cough and any other

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<sup>1</sup> While other impact areas exist, the focus falls here on the three major areas.

chest illness keeping the sufferer in bed for more than two days (Terblanche,1992).

Von Schirnding, Yach and Klein (1991) clearly show the high incidence of childhood deaths due to ARI's in South Africa. They cite several references which come to the same conclusion, some going so far as to point out that pneumonia is the second most common cause of childhood mortality in South Africa. Utilising the Republic of China's case-fatality ratio of 21.4% for children hospitalised with pneumonia, they estimate that 13000 infants require hospitalisation for pneumonia each year in South Africa.

Two points of criticism seem obvious as far as this analysis is concerned. Firstly, as they themselves point out, data for black infants are highly suspect, but if anything, underreported. Secondly, the use of Chinese case-fatality ratios is questionable. Studies from Rwanda, Uganda, Zaire, Zambia and Zimbabwe (Kirkwood,1991) estimate case-fatality ratios of between 10 and 20 percent. This seems to place a questionmark over the use of a case-fatality ratio of 21.4%. However, it still justifies concern over the possible impact that electrification will have on this range of disorders.

A number of epidemiological studies have been conducted examining the link between air pollution and health. For the most part, these studies take the form of either cross-sectional or case-control analyses (see Appendix B for a review of some of these studies). It is very difficult to establish causality in these types of studies. Longitudinal data is far more reliable when investigating causality. Ozkaynak (1993), in summarising the results from several cross-sectional studies done internationally, concludes that air pollution related mortality seems to be functionally dependent only on fine particles ( $PM_{2.5}$ ) and sulphates. The dependence of respiratory infection on sulphates and other smaller particles is examined by recent medical research (Ostro,1993;Hoek & Brunekreef,1993). Ozkaynak's (1993) study also summarises the main results of international time-series analyses of the health effects of air pollution. He concludes that in general, one can expect a 1% increase in mortality and a 2% increase in morbidity due to respiratory infections for every  $10\mu\text{gm}^{-3}$  increase in daily  $PM_{10}^2$  exposure. This result is also confirmed by recent medical literature (Ostro,1993; Hoek & Brunekreef,1993).

To use this last result, it is necessary to show exactly to what extent daily exposure to  $PM_{10}$  (measured in  $\mu\text{gm}^{-3}$ 's) will change due to electrification. This will be achieved by using three sources of information. The first is the result of the methodology outlined above which estimated the switch to electricity that is expected to take place once wider access to electricity is provided. The second is that electrified HH's can be expected to produce less air pollution than do non-electrified HH's (Smith,1988). This information can be used in conjunction with current HH fuel consumption data, as is contained in Tables 2-12 (EDRC,1993), and fuel emission data (Table 16) (Smith,1988) to calculate the expected percentage reduction in HH air

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<sup>2</sup>  $PM_{10}$  is defined as airborne particles of 10 microns or less in diameter.

pollution production. Combining the result of such a calculation with information on current exposure levels, based on the assumption that ambient air pollution levels are to some extent determined by HH fuel use, allows one to calculate the expected reduction in  $PM_{10}$  exposure levels, measured in  $\mu\text{gm}^{-3}$ 's, due to electrification. This methodology is quite complicated and will now be elaborated on.

The first task is to calculate the expected reduction in HH air pollution production. It is assumed that electrical appliances add nothing to air pollution levels<sup>3</sup>. Table 16 provides some useful information as regards the polluting characteristics of four alternative 'dirty' fuels (Smith, 1988). Using this information in combination with the monthly energy consumption figures as depicted by Tables 2 - 12 (EDRC, 1993) the expected monthly pollution production in kilograms of a typical electrified and non-electrified HH is calculated using the following equation:

$$HH \text{ air pollution} = 1/3 \cdot (TSP_E + SO'S_E + CO_E) + 2/3 \cdot (TSP_{NE} + SO'S_{NE} + CO_{NE}) \quad (1)$$

where  $TSP_E$ ,  $SO'S_E$ ,  $CO_E$ ,  $TSP_{NE}$ ,  $SO'S_{NE}$  and  $CO_{NE}$  denote the production levels of total suspended particulates, sulphur oxides and carbon monoxide generated by electrified and non-electrified HH's respectively, as can be found in tables 2-12. This is the air pollution production of a typical HH assuming that on average 1/3 of all townships are electrified. This information will be used to establish the expected reduction in HH pollution levels once electrification takes place.

To calculate the expected percentage reduction in HH air pollution production once electrification takes place utilising the switching patterns established before, data on the number of HH's under consideration is required. This data is not readily available for all areas under study. Where this data is lacking, it will again be assumed that in general the currently electrified HH's constitute 1/3 of any area. Combining this with the information about the percentage of non-electrified HH's expected to switch to electricity, denoted by  $S$ , the percentage drop in HH air pollution production, taking only TSP, sulphur oxides and CO into account (due to Ozkaynak's (1993) insistence on a lack of functional dependency between mortality or morbidity and nitrogen oxides) is expected to be:

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<sup>3</sup> We are not referring to the pollution produced by power stations. However, it has been shown (Turner et al, 1990) that Eskom is very successful in removing  $PM_{10}$  from their emissions.

$$\% \text{ change in HH air pollution} = \frac{S \cdot 2/3 \cdot (TSP_E - TSP_{NE} + SO'_S - SO'_{S_{NE}} + CO_E - CO_{NE})}{HH \text{ air pollution}} \cdot 100 \quad (2)$$

This calculation can be performed for all the areas under study simply by substituting the relevant previously calculated rate of substitution of electricity for other fuels in that area.

The next task is to convert this percentage decrease in HH air pollution production into a reduced ambient air pollution level. A very simplistic but probably quite accurate assumption that there exists a linear relationship between the amount of HH air pollution and the ambient air pollution level will be made. In other words:

$$\text{Ambient air pollution} = f(\text{HH air pollution}) \quad (3)$$

This assumption leads to the conclusion that ambient air pollution levels will fall by exactly the same percentage as HH air pollution production. The expected percentage change in emissions can therefore be converted into an expected change in pollution levels measured in  $\mu\text{gm}^{-3}$ 's. This process is complicated due to the lack of data on current exposure levels in most areas. However, where data is not available exposure levels of other areas will be applied. The exposure levels used will be an average of levels measured on winter and summer days. Due to a lack of data, an exposure level of  $1000 \mu\text{gm}^{-3}$  is used for areas where coal and wood dominate as alternative fuels, and  $500 \mu\text{gm}^{-3}$  for areas where paraffin and LPG dominate.

The reduced levels of air pollution (now measurable in  $\mu\text{gm}^{-3}$ 's) will yield the expected percentage reduction in mortality and morbidity due to reduced air pollution levels when substituted into the following two equations which come directly from Ozkaynak's(1993) time-series analysis:

$$\frac{d(\text{Mortality})}{\text{Mortality}} \cdot 100 = \frac{1}{10} \cdot d(\text{PM}_{10}) \quad (4)$$

$$\frac{d(\text{Morbidity})}{\text{Morbidity}} \cdot 100 = \frac{2}{10} \cdot d(\text{PM}_{10}) \quad (5)$$

To restate Ozkaynak's results - they model an environment in which firstly, mortality from air pollution, related primarily to exposure to suspended particles referred to as  $\text{PM}_{10}$  due to their size, increases by 1% for every  $10\mu\text{gm}^{-3}$  increase in daily  $\text{PM}_{10}$  exposure levels. Secondly, they model morbidity from air

pollution in the same way, with the difference that morbidity increases by 2% for every  $10\mu\text{gm}^3$  increase in daily  $\text{PM}_{10}$  exposure levels.

Having applied this methodology the expected percentage reduction in morbidity and mortality due to respiratory infections resulting from electrification would have been established.

The methodology that will be utilised to establish the impact of reduced use of paraffin as a source of HH energy on health will be analyzed in the next section.

### 1.2.2. Paraffin use and health

The most significant health implication of paraffin use is a high number of paraffin poisoning cases, especially among children. It is generally believed that this results mainly from the fact that paraffin is very often kept in cooldrink bottles leading to children mistaking paraffin for cooldrink or water. It has been estimated that at least 16000 children are hospitalised each year for paraffin poisoning (Yach, in press). Yach contends that the total health impact of paraffin use is 30 hospitalisation cases for every 1 million litres of HH paraffin sold each year (Yach, in press).

The implication of this for the current study is that increased use of electricity in place of paraffin will therefore lead to reduced paraffin poisoning cases. To use this result it is again necessary to calculate the exact extent to which this switch will occur (measured in millions of litres of HH paraffin consumption).

A similar analysis as was applied above to calculate the expected reduction in HH air pollution production can be used to determine the expected reduction in HH paraffin use. The expected monthly fuel consumption of a typical electrified and non-electrified HH in any area can be calculated by using the energy consumption and fuel efficiency figures supplied by Tables 2-12 (EDRC, 1993) and Table 16 (Smith, 1988) respectively. This figure can be translated into an annual figure aggregated over all HH's by multiplying the previous figure by a factor of 12, as well as by including the number of HH's under consideration. Recalculating this figure, taking into account the extent to which HH's are expected to switch to electricity for all their HH energy needs once electrified, allows one to calculate the reduction in annual paraffin sales for HH consumption. This information can be used in the following equation, which is a mathematical representation of Yach's (in press) postulate above:

$$d(\text{Morbidity}) = \frac{30}{1 \text{ million}} \cdot d(\text{Paraffin use}) \quad (6)$$

Applying this equation to all the areas for which data exists on the number of HH's under consideration results in a prediction about the expected reduction in paraffin poisonings hospitalised after electrification.

### 1.2.3. Burns

This section will outline the methodology to be used to analyze the effect of electrification on the number of burn victims in South Africa once wider access to electricity is provided.

Burns can result both from the utilisation of energy and from the energy source itself. For instance, a Nigerian study (Stansfield,1992) of hospital admissions for burns in children from birth to 15 years found that scalds from hot water or tea were responsible for 64% of the admissions, cooking oil for 13%, gas stoves or petroleum explosion for 7%, naked fires for 6% and motorcycle exhausts for 5%. This shows that 77% of the cases resulted from energy utilisation, and only 13% from the energy source itself. The Cape metropolitan trauma study performed by the Medical Research Council (Abrahams,1994) shows that 58.19% of burn injuries resulted from hot liquids, 27.92% from fire, 9.63% from chemicals, and 4.26% from electricity. Furthermore, a study done in Turkey (Stansfield,1992) showed that electrical burns constituted 19% of burn centre admissions. In Menoufia, Egypt (Stansfield,1992) it was found that portable kerosene and gas stoves were responsible for 63% of deaths from burns among women of reproductive age. These figures indicate the complexity of investigating the effect that electrification will have on the number of burn victims. However, considering the importance of domestic use of hot liquids as a leading cause of burn injuries, it is clear that most burn injuries occur at home. Thus, HH electrification should impact significantly on the number of burn injuries in South Africa.

Whites not only have less contact with open fires due to the use of electricity, but they also have safer appliances - safer being defined here both as leading to fewer direct energy use burn accidents as well as fewer energy utilisation accidents. For instance, a pot of boiling water is far securer on an electric stove than on a small primus stove, leading to a reduced risk of being burnt by spilt liquids. Thus, it seems quite reasonable to use mortality, morbidity and case-fatality ratios of white electrified areas as a proxy for the position that currently non-electrified areas would find themselves in once electrified. Clearly this is only a proxy, since access to medical care, transportation, access to water (quick home treatment of burns) and knowledge of and access to electrical appliances differ among the two groups and have significant influence on morbidity and mortality rates. Furthermore, this methodology will result in a prediction about the reduction in burns that will be experienced over some time period since newly electrified areas can only be expected to experience mortality rates similar to those currently faced by white HH's once they have been electrified for a similar period.

A study done by Kibel et al (1990) in South Africa shows that coloured and black patients treated for flame

burns outnumbered white patients (age, under 13 years) by a factor of 18.5 and 20.9 respectively. In general burns constituted 11% of overall causes of injuries treated. Burns also had one of the highest admission rates at over 20%. This is confirmed by the above mentioned Cape Metropolitan (Abrahams, Unpublished data 1994) study where 17.75% of all burn cases were admitted after initial treatment. It is also pointed out that burns have one of the highest case-fatality ratios among children in South Africa. However, 80% of the burns were scalds (hot fluids). This data not only reaffirms the importance of burns as a determinant of morbidity and mortality in South Africa, but emphasises its amplified impact on the disadvantaged groups of South Africa.

Two quite different approaches were used to calculate the impact of electrification, and are referred to as 'Census' and 'Calculated' respectively. Both methods use the 1991 census (Census, 1991) figures for population size. However, this is where the resemblance ends. The 'Census' method takes the number of reported deaths due to all causes and due to fire as reported in the 1990 census report on deaths (Census, 1990) as given. The deaths due to burns as a percentage of total deaths is then calculated, eg. 1.23% for 1-4 year old whites. In contrast, the 'Calculated' method uses the overall mortality rate as calculated by Bradshaw et al (1992) (it was calculated taking into account underreporting of black deaths) and calculates the total number of deaths. The percentage of burn deaths in total deaths as was calculated in the 'Census' method is assumed to be constant, and is used in the 'Calculated' method to calculate the number of burn deaths. An overall mortality rate is also calculated for the 'Census' method purely based on reported total deaths. At this point the population size and the number of deaths due to burns is known for both methods. Burn mortality rates for both methods can therefore be calculated. A comparison with international mortality rates show that these are quite plausible for all age groups. Using a fatality-case ratio (FCR) as calculated from the results of the Cape Metropolitan study (Abrahams, Unpublished data 1994), the total number of burn cases can now be estimated. Due to a lack of data, it is assumed that the FCR will be the same for all population groups, based essentially on the assumption that the severity of burns do not differ amongst race groups and that they have access to the same quality health service. A FCR of 78.75 is used. This must be clarified. It indicates the ratio of deaths due to burns (both pre-hospital and post-hospital deaths) to total number of cases in the Cape Metropolitan area. It is therefore being used as a proxy for the FCR's in all other areas of South Africa. To make this proxy more acceptable, taking into account the size of the sample, a 95% confidence interval is calculated. It ranges from a FCR of 65.79 to a FCR of 92.59.

The impact of electrification on the estimated number of burn cases for 1991 can now be analyzed. Using a simple average and the results of the modelling methodology outlined before, it is calculated that 69% of the currently non-electrified HH's will switch to electricity as their sole energy-carrier on a national basis.

In the first 'Census' case, the following calculation is used to establish the number of burn cases after

complete electrification:

$$\begin{aligned}
 \text{Nr. burn cases} = & (0.69) \cdot \frac{\text{Population}}{1000} \cdot MR_{\text{White,Census}} \cdot \frac{\text{Burn deaths}_{\text{White,Reported}}}{\text{Total deaths}_{\text{White,Reported}}} \cdot \text{FCR} \\
 & + (1-0.69) \cdot \frac{\text{Population}}{1000} \cdot MR_{\text{Other race,Census}} \cdot \frac{\text{Burn deaths}_{\text{Other race,Reported}}}{\text{Total deaths}_{\text{Other race,Reported}}} \cdot \text{FCR}
 \end{aligned} \tag{7}$$

where

Population -	Total population of particular age group and race;
$MR_{\text{White,Census}}$ -	Mortality rate for whites, as calculated from the total number of deaths and population size reported in the census.
$MR_{\text{Other race,Census}}$ -	Mortality rate for any non-white race in question, as calculated from the total number of deaths and population size reported in the census.
$\text{Burn deaths}_{\text{White,Reported}}$ -	The total number of deaths due to burns for whites as reported in the census.
$\text{Burn deaths}_{\text{Other race,Reported}}$ -	The total number of deaths due to burns for the race in question as reported in the census.
$\text{Total deaths}_{\text{White,Reported}}$ -	The total number of deaths for whites as reported in the census.
$\text{Total deaths}_{\text{Other race,Reported}}$ -	The total number of deaths due to burns for the race in question as reported in the census.
FCR -	Fatality-case ratio.

Application of this method implicitly assumes that the number of reported deaths and the percentage of burn deaths out of total deaths is accurate. The result of this calculation under the 'Census' method may be referred to as the status 'After electrification'.

In the 'Calculated' case the following calculation is applied, also to establish the expected number of burn cases after total electrification:

$$\begin{aligned}
\text{Nr. burn cases} &= (0.69) \cdot \frac{\text{Population}}{1000} \cdot \text{Burn MR}_{\text{White, Calculated}} \cdot \text{FCR} \\
&+ (1-0.69) \cdot \frac{\text{Population}}{1000} \cdot \text{Burn MR}_{\text{Otherrace, Calculated}} \cdot \text{FCR}
\end{aligned} \tag{8}$$

where 'Population' and 'FCR' are defined as above and

$$\text{Burn MR}_{\text{White, Calculated}} = \frac{\text{Calculated burn deaths}_{\text{White}} * 1000}{\text{Population}_{\text{White}}} \tag{9}$$

$$\text{Burn MR}_{\text{Other race, Calculated}} = \frac{\text{Calculated burn deaths}_{\text{Other race}} * 1000}{\text{Population}_{\text{Other race}}} \tag{10}$$

It is still assumed that the percentage of burn deaths out of total deaths is accurate, but it is no longer as dependent on the accuracy of total deaths on its own due to the fact that a mortality rate calculated specifically accounting for inaccurate death reporting is being used.

Both approaches result in a prediction about the expected reduction in burns after electrification based on a range of FCR's. When it comes to using the results of these calculations, a simple average of the results of the two methods will be used.

### 1.3. Quantifying the health benefits of electrification.

An attempt will be made to translate the 'health saving' identified above into an 'economic saving' by investigating the impact of the electricity associated reduction in morbidity and mortality on the health services sector of the South African economy. Only the direct cost saving based on the direct health benefits of electrification will be calculated.

The work on the economic cost of cardiovascular disease performed by Pestana(1993) for costing methodology will be followed closely. Pestana (1993) shows a breakdown of direct costs associated with cardiovascular disease in South Africa in 1991. It is shown that transport, private hospitals, general practitioners, public hospitals, drugs and physicians together constitute on average 99.6% of total direct costs of cardiovascular disease in South Africa.

The same basic procedure as that in Pestana (1993) will be applied to each of the three areas identified as benefitting from electrification, namely respiratory infections, paraffin poisonings and burns. However, private hospitalisation costs will be ignored because the income group of interest in this thesis will not make use of these facilities to any great extent. Due to a lack of data at the time of writing this thesis, drug costs will also be ignored. This methodology will enable a calculation of the current total economic cost of respiratory infections, paraffin poisoning and burns to the South African economy. Using the information provided earlier a recalculation of this economic cost after taking into consideration the impact of electrification will be done. This will identify the direct economic saving from electrification.

The first category of direct costs are transportation costs. Transportation costs are divided into 4 categories: The total cost of public and private transport to general practitioners (GP's), specialists and hospitals and the total cost of ambulance transport to hospital.

### 1.3.1. Total cost of transport to GP's

The total cost of public and private transport to GP's is calculated using the following equation:

$$Total\ cost\ of\ transport\ to\ GP's = PubT \cdot (I \cdot Cost_{PubT} \cdot 2) + PriT \cdot (I \cdot Cost_{PriT} \cdot AD) \quad (11)$$

Where

- I - The number of GP contacts associated with black, coloured and Asian respiratory infection, paraffin poisoning or burn cases. This is calculated using the total number of GP contacts (Pestana,1993), the fraction of GP contacts that are black, coloured and Asian (Zwarenstein,in press) and the fraction of all GP contacts due to respiratory infections, paraffin poisoning or burn cases (Bourne,1993).
- PubT - The fraction of I assumed to use public transport (50%).
- PriT - The fraction of I assumed to use private transport (50%). Note that PubT + PriT = 1.
- Cost<sub>PubT</sub> - The cost of public transport (Pestana,1993).
- Cost<sub>PriT</sub> - The cost of private transport per kilometre(Pestana,1993).

AD - The assumed average distance travelled to a GP.

It is assumed that 50% of the GP contacts use public and 50% private transport and that the average distance travelled to and back from the GP is 6 kilometres.

### 1.3.2. Total cost of transport to Specialists

The total cost of public and private transport to specialists is calculated as above, except that specialist contacts (Bourne, in press) instead of GP contacts is used.

### 1.3.3. Total cost of ambulance transport to hospital

The total cost of ambulance transport to hospital is calculated as follows:

$$\text{Total cost of ambulance transport} = NAB \cdot FI \quad (12)$$

where

NAB - National Ambulance Budget, calculated by taking the Cape Province ambulance budget (Pestana, 1993) and scaling it up according to the size of the Cape Province population relative to the population of all of the South African provinces, ie. South African provinces population/Cape province population (Census, 1991).

FI - The fraction of total conveyances by ambulance accounted for by black, coloured and Asian respiratory infections, paraffin poisonings and burns respectively (Pestana, Personal communication 1994). The data on ambulance conveyances is not stratified according to race. Instead, the ratio of black, coloured and Asian hospital discharges (Census of hospitals, 1990) due to respiratory infections, paraffin poisonings and burns to total discharges for these illnesses is taken as a proxy for the percentage of ambulance trips that are black, coloured or Asian cases for each respective illness. Furthermore, since the discharge data only lists poisonings, accidents and violence together, this proxy percentage is the same for burns and paraffin poisoning. Due to lack of data this is the best approximation.

### 1.3.4. Total cost of public & private transport to hospital

Since the number of black, coloured and Asian patients discharged from hospital as well as the number of

these transported by ambulance is known, the rest must have used either public or private transport. The one-way trip made by those who died in hospital is not taken into account. Making similar assumptions to those made when calculating the cost of public and private transport to GP's and specialists, (except that the average distance travelled is now assumed to be 20km) enables one to calculate the total cost of public and private transport to hospital. The reason why paraffin poisoning and burns cases are grouped together here is simply due to the lack of more disaggregated data (Census,1991).

#### **1.3.5. Total GP consultation cost**

The second category of costs is associated with black, coloured and Asian respiratory infection, paraffin poisoning and burn GP and Specialist consultations. The number of contacts constituted by each illness has already been calculated when calculating the transportation cost to GP's. It is now simply a question of multiplying the total number of contacts by the GP consultation rate. Two rates are generally quoted, namely the MASA rate and the S/B rate. Due to the fact that lower-income groups are generally offered the lower S/B rate, this rate is used in the calculation (Pestana,1993).

#### **1.3.6. Total Specialist consultation cost**

Specialist consultation costs were calculated in a similar way, except that the an S/B rate of R100 is used.

#### **1.3.7. Total state hospitalisation cost**

The third category of costs are costs associated with hospitalisation. The total cost of hospitalisation for black, coloured and Asian respiratory infections and paraffin poisonings and burns in state hospitals is found using the following equation:

$$\text{Total state hospitalisation cost} = HB \cdot DI \cdot CWF \quad (13)$$

where

HB - Annual budget of state hospitals in South Africa (Pestana,1993).

DI - Black, coloured and Asian discharges due to respiratory infections, paraffin poisonings and burns as a fraction of the total discharges due to these illnesses (Census of hospitals,1990).

**CWF - A cost weighting factor, meant to indicate the cost of treating respiratory infections, paraffin poisonings and burns relative to the cost of treating other illnesses.**

**Application of this costing methodology will yield an estimate of the direct cost saving in the health services sector of the South African economy resulting from the health benefits of electrification.**

**Table 1 : Analysis of all urban households.**

	PWV	DFR/Pietermaritzburg	Cape Tow	PE/EL	Kimberley	OFS
Total number	1000000	300000	120000	300000		
Only Coal						
Only gas						
Only paraffin		261000				
Only candles						
Only wood						
Only electricity						
Coal & Elec.						
Electrified	320000				9000	
Analysis of electrified:						
Only Coal						
Only gas						
Only paraffin						
Only candles						
Only wood						
Only electricity	176000					
Coal & Elec.	144000				3150	
Non-Electrified	680000					
Analysis of non-electrified:						
Only Coal	544000					
Only gas						
Only paraffin						
Only candles						
Only wood						

(Source : EDRC,1993)

**Table 2 : Analysis of fuel use in PWV**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	1223	36.42	3000.5	73.80	0.67	1.25	6.46	0.33	1.65	3.30	15.90	0.81	60.69	146.91
Gas	5	0.15	32.29	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.84
Paraffin	115	3.42	632	16.04	0.00	0.13	0.00	0.01	0.01	0.78	0.01	0.05	3.09	17.53
Candles	5	0.15	96	2.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	210	6.25	271.5	6.68	0.57	0.01	3.57	0.02	0.73	0.01	4.62	0.03	23.33	30.17
Electricity	1800	53.80	11.25	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>3356.00</b>	<b>100.00</b>	<b>4065.50</b>	<b>100.00</b>	<b>1.24</b>	<b>1.49</b>	<b>10.05</b>	<b>0.38</b>	<b>2.39</b>	<b>4.07</b>	<b>20.53</b>	<b>0.89</b>	<b>87.25</b>	<b>197.45</b>

**Table 3 : Analysis of fuel use in DFR/Pletermaritzburg**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	405	20.83	647.25	37.53	0.22	0.45	2.15	0.11	0.47	0.93	4.49	0.23	20.10	42.00
Gas	10	0.32	313.75	13.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.26	8.20
Paraffin	16	0.83	717.75	31.79	0.00	0.02	0.00	0.00	0.01	0.84	0.01	0.05	0.43	19.30
Candles	47	2.43	79.25	3.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	17	0.86	266.25	12.77	0.05	0.00	0.29	0.00	0.78	0.01	4.90	0.03	1.89	32.03
Electricity	1440	74.42	11.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1935.00</b>	<b>100.00</b>	<b>2257.50</b>	<b>100.00</b>	<b>0.27</b>	<b>0.46</b>	<b>2.44</b>	<b>0.11</b>	<b>1.25</b>	<b>1.78</b>	<b>9.41</b>	<b>0.32</b>	<b>22.68</b>	<b>101.58</b>

**Table 4 : Analysis of fuel use in Cape Town**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	1	0.05	43.5	3.39	0.00	0.00	0.01	0.00	0.02	0.05	0.23	0.01	0.05	2.16
Gas	44	2.27	220.25	17.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.15	5.76
Paraffin	135	6.95	699.75	54.52	0.00	0.16	0.00	0.01	0.01	0.82	0.01	0.05	3.83	18.82
Candles	1	0.05	77.5	6.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	5	0.26	231.25	18.02	0.01	0.00	0.09	0.00	0.82	0.01	3.93	0.02	0.56	25.69
Electricity	1736	80.42	11.25	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1942.00</b>	<b>100.00</b>	<b>1283.50</b>	<b>100.00</b>	<b>0.02</b>	<b>0.16</b>	<b>0.09</b>	<b>0.01</b>	<b>0.86</b>	<b>0.87</b>	<b>4.18</b>	<b>0.09</b>	<b>5.39</b>	<b>52.43</b>

(Sources : EDPC, 1993, Smith, 1988)

**Table 5 : Analysis of fuel use in Port Elizabeth/East London**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	0	0.00	21.75	2.13	0.00	0.00	0.00	0.00	0.01	0.02	0.12	0.01	0.00	1.08
Gas	79	6.31	101	9.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.07	2.94
Paraffin	271	21.66	720.75	70.70	0.00	0.32	0.01	0.02	0.01	0.84	0.01	0.05	7.29	19.38
Candles	1	0.08	15.25	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	0	0.00	149.5	14.66	0.00	0.00	0.00	0.00	0.40	0.00	2.54	0.01	0.00	16.81
Electricity	900	71.94	11.25	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1251.00</b>	<b>100.00</b>	<b>1019.50</b>	<b>100.00</b>	<b>0.00</b>	<b>0.32</b>	<b>0.01</b>	<b>0.02</b>	<b>0.42</b>	<b>0.87</b>	<b>2.67</b>	<b>0.06</b>	<b>9.35</b>	<b>30.71</b>

**Table 6 : Analysis of fuel use In Orange Free State**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	49	5.24	2077.5	61.93	0.03	0.05	0.26	0.01	1.14	2.29	11.01	0.56	2.43	103.10
Gas	15	1.60	112.75	3.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	2.95
Paraffin	111	11.67	652.75	19.46	0.00	0.13	0.00	0.01	0.01	0.78	0.01	0.05	2.86	17.50
Candles	6	0.64	109.25	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	34	3.64	394.25	11.75	0.09	0.00	0.58	0.00	1.06	0.01	6.70	0.04	3.78	43.81
Electricity	720	77.01	11.25	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>935.00</b>	<b>100.00</b>	<b>3254.75</b>	<b>100.00</b>	<b>0.12</b>	<b>0.18</b>	<b>0.84</b>	<b>0.03</b>	<b>2.22</b>	<b>3.06</b>	<b>17.73</b>	<b>0.65</b>	<b>9.59</b>	<b>167.41</b>

**Table 7 : Analysis of fuel use in Kimberley**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	501	35.31	339.75	20.33	0.28	0.55	2.66	0.14	0.19	0.37	1.60	0.08	24.86	16.86
Gas	0	0.00	100.5	6.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63
Paraffin	76	5.36	708.25	42.44	0.00	0.09	0.00	0.01	0.01	0.63	0.01	0.05	2.04	19.07
Candles	104	7.33	66.5	4.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	54	3.81	441.75	26.44	0.15	0.00	0.92	0.01	1.19	0.01	7.51	0.04	6.00	49.06
Electricity	694	49.20	11.25	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1419.00</b>	<b>100.00</b>	<b>1671.00</b>	<b>100.00</b>	<b>0.42</b>	<b>0.64</b>	<b>3.57</b>	<b>0.15</b>	<b>1.39</b>	<b>1.22</b>	<b>9.33</b>	<b>0.19</b>	<b>32.91</b>	<b>67.64</b>

(Sources : EDRC, 1993, Smith, 1998)

**Table 8 : Percentage MJ contributed by each fuel in the HH sector of the homelands/self-governing states of South Africa.**

Homeland/Self-governing state	Coal	Candle	LP Gas	Paraffin	Wood	Electricity
Bophuthatswana	5	2	1	12	80	0
Ciskei	0	0	0	8	92	0
Gazankulu	3	1	2	8	86	0
KaNdwane	1	1	0	8	90	0
KwaNdebele	17	1	2	14	66	0
KwaZulu	17	1	2	14	66	0
Lebowa	1	1	0	8	90	0
QwaQwa	82	1	1	9	6	0
Transkei	4	1	1	10	84	0
Venda	3	1	2	8	86	0

(Source : EDRC,1993)

**Table 9 : Analysis of fuel use in Namaqualand**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)		
	Electrified (Kimberley)	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified	
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides			
Coal	501	35.31	0	0.00	0.28	0.55	2.68	0.14	0.00	0.00	0.00	0.00	0.00	24.88	0.00
Gas	0	0.00	1142	23.85	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.04	0.00	29.88
Paraffin	78	5.36	353	7.37	0.00	0.09	0.00	0.01	0.00	0.41	0.01	0.01	0.03	2.04	8.48
Candles	104	7.33	44	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	54	3.81	3055	63.81	0.15	0.00	0.82	0.01	8.25	0.09	51.84	0.31	6.00	309.44	0.00
Dung	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crop waste	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petrol/Diesel	0	0.00	32	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
Electricity	684	48.20	182	3.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1419.00</b>	<b>100.00</b>	<b>4788.00</b>	<b>100.00</b>	<b>0.42</b>	<b>0.64</b>	<b>3.57</b>	<b>0.15</b>	<b>8.24</b>	<b>0.50</b>	<b>51.68</b>	<b>0.38</b>	<b>32.91</b>	<b>379.83</b>	

**Table 10 : Analysis of fuel use in Bophuthatswana**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified (Kimberley)	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	501	35.31	225	4.33	0.28	0.55	2.68	0.14	0.12	0.25	1.19	0.08	24.88	11.17
Gas	0	0.00	87	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75
Paraffin	78	5.36	500	9.82	0.00	0.09	0.00	0.01	0.01	0.59	0.01	0.04	2.04	13.45
Candles	104	7.33	83	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	54	3.81	3300	63.48	0.15	0.00	0.82	0.01	8.91	0.10	58.10	0.33	8.00	386.67
Dung	0	0.00	1000	19.23	0.00	0.00	0.00	0.00	2.70	0.03	17.00	0.10	0.00	111.11
Crop waste	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petrol/Diesel	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	684	48.20	25	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1419.00</b>	<b>100.00</b>	<b>5200.00</b>	<b>100.00</b>	<b>0.42</b>	<b>0.64</b>	<b>3.57</b>	<b>0.15</b>	<b>11.74</b>	<b>0.98</b>	<b>74.30</b>	<b>0.53</b>	<b>32.91</b>	<b>504.14</b>

**Table 11 : Analysis of fuel use in Gazankulu,Venda,KaNgwane and Lebowa.**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified (Kimberley)	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	501	35.31	205	3.03	0.28	0.55	2.68	0.14	0.11	0.23	1.09	0.08	24.88	10.17
Gas	0	0.00	39	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.54
Paraffin	78	5.36	467	8.91	0.00	0.09	0.00	0.01	0.01	0.55	0.01	0.03	2.04	12.56
Candles	104	7.33	86	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	54	3.81	5457	80.69	0.15	0.00	0.82	0.01	14.73	0.18	82.77	0.55	8.00	606.33
Dung	0	0.00	473	8.99	0.00	0.00	0.00	0.00	1.28	0.01	8.04	0.05	0.00	52.56
Crop waste	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petrol/Diesel	0	0.00	36	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
Electricity	684	48.20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1419.00</b>	<b>100.00</b>	<b>6763.00</b>	<b>100.00</b>	<b>0.42</b>	<b>0.64</b>	<b>3.57</b>	<b>0.15</b>	<b>16.13</b>	<b>0.95</b>	<b>101.81</b>	<b>0.89</b>	<b>32.91</b>	<b>684.10</b>

(Sources : EDPC,1993;Smith,1988)

**Table 12 : Analysis of fuel use in Transkel/CisKel**

Fuel	Monthly household energy consumption in delivered MJ				Expected monthly household pollution production (in kg's)								Calculated monthly HH fuel consumption (in kg's)	
	Electrified (Kwhberley)	As % of Electrified	Non Electrified	As % of Non-Electrified	Electrified				Non-Electrified				Electrified	Non Electrified
					TSP	Sulfur Oxides	CO	Nitrogen Oxides	TSP	Sulfur Oxides	CO	Nitrogen Oxides		
Coal	501	35.31	114	1.87	0.28	0.55	2.68	0.14	0.06	0.13	0.60	0.03	24.86	5.68
Gas	0	0.00	20	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
Paraffin	78	5.36	422	6.92	0.00	0.09	0.00	0.01	0.00	0.48	0.01	0.03	2.04	11.35
Candles	104	7.33	40	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	54	3.81	4326	74.27	0.15	0.00	0.92	0.01	12.22	0.14	78.94	0.45	6.00	502.88
Dung	0	0.00	835	13.70	0.00	0.00	0.00	0.00	2.23	0.03	14.20	0.08	0.00	92.78
Crop waste	0	0.00	137	2.25	0.00	0.00	0.00	0.00	0.37	0.00	2.33	0.01	0.00	15.22
Petrol/Diesel	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	884	48.20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1419.00</b>	<b>100.00</b>	<b>6094.00</b>	<b>100.00</b>	<b>0.42</b>	<b>0.64</b>	<b>3.57</b>	<b>0.15</b>	<b>14.91</b>	<b>0.78</b>	<b>94.08</b>	<b>0.61</b>	<b>32.91</b>	<b>628.42</b>

(Sources : EDPC,1993;Smith,1998)

**Table 13 : Average % of farmworker HH's using different fuels for cooking, heating and lighting.**

Purpose	Fuelwood	Farm Waste	Coal	Paraffin	LPG	Candles	Electricity
Cooking & Heating	91	20	6	21	4	0	3
Lighting	5	0	0	62	3	75	18

(Source : EDRC,1993)

**Table 14 : Fuel use in electrified and non-electrified farmworker HH's**

Energy carrier	Non-electrified HH's	Electrified HH's
Fuelwood	91	85
Paraffin	62	25
Coal	7	8
Agricultural (Farm) Waste	25	10
Candles	63	29
Batteries (all type)	15	13

(Source : EDRC,1993)

**Table 16 : General analysis of fuel use**

Fuel	MJ/kg	Stove efficiency %	Fuel/1000GJ (Metric tons)	Kg's of pollutant/1000GJ's delivered			
				TSP	Sulfur Oxides	CO	Nitrogen Oxides
Coal	31	65	49.63	550	1100	5300	270
Gas	45	85	26.14	7	0	10	38
Paraffin	43.75	85	26.89	11	1170	20	71
Wood	18	50	111.11	2700	30	17000	100

(Source : Smith,1988)

## Chapter 2. Modelling expected electricity use

This chapter presents the results based on the methodology outlined in the previous chapter. All the data used to model expected future electricity use comes from the EDRC Epret database (1993).

### 2.1. Modelling expected electricity use in the urban areas of South Africa.

There are approximately 7.5 million HH's in South Africa. Of these, 30% (2.25m) are mid- to high income earning. This is a predominantly white racial group. A further 30% are defined as the urban poor, and the last 40% (3m) the rural poor. These last two groups contain the majority of the black population. It is the urban poor group, constituting 2.25 million HH's that this section focuses on.

The poor urban areas of South Africa consist firstly of the main metropolitan areas namely the PWV(1m HH's), the Durban functional region(DFR) and Pietermaritzburg(0.3m HH's), Cape Town(0.12m HH's) and Port Elizabeth and East London(0.3m HH's) (See Table 1). The other urban centres are defined as towns and closer settlements which together constitute about 0.53m HH's and include Bloemfontein, Cradock and Klerksdorp.

As was outlined before, a comparison of non-electrified groups and the currently electrified groups in these areas is made and an attempt is made to predict the extent to which non-electrified HH's will switch electricity as their sole energy-carrier if broad access to electricity is provided.

#### 2.1.1. Pretoria/Witwatersrand/Vereeniging (PWV)

Data on the PWV is particularly complete. There are 1 million (1m) HH's in this area (See Table 1). Of these, 0.32m are electrified and 0.68m are non-electrified. Coal dominates as alternative fuel in the PWV as can be seen from Figure 1. Of the electrified HH's, 54% (0.173m HH's) use only electricity as an energy-carrier. 36% (0.115m HH's) out of the remaining 46% (0.147m HH's) use both coal and electricity (and perhaps some other fuels as will be pointed out below) as an energy-carrier. Of the 0.68m non-electrified HH's, 80% (0.544m HH's) use only coal. Thus it can be concluded that approximately 0.66m HH's (0.115m + 0.544m) in the PWV still use coal. This pattern of fuel use is also reflected in the delivered monthly energy figures (Table 2).

0.69m HH's in the PWV are have coal stoves. Thus, it must be concluded that every electrified and non-electrified coal-using HH has a coal stove. The importance of this finding is that *every coal-using*

*electrified HH still uses a coal stove.*

25% of the electrified HH's still use candles for lighting purposes. 55% of the HH's use electricity for space-heating. This figure, due to its similarity with the percentage of electrified HH's using electricity only, seems to indicate that the HH's who own coal stoves, do not use electricity for space-heating.

These figures indicate that an electrified HH is still using coal (36% in PWV) is using it for cooking, space-heating and water-heating. Some are also still using candles for lighting, however, probably only as a backup when the electricity supply fails.

The conclusion is that 54% ( $S(PWV)=0.54$ ) of the currently non-electrified group in the PWV can be expected to switch from coal to electricity as their sole energy-carrier once they are provided with access to electricity. The rest will continue using mainly coal, but also some other fuels. This translates into an additional 0.367m HH's using electricity as their sole energy-carrier.

#### **2.1.2. Durban Functional Region(DFR) & Pietermaritzburg**

This area is characterised by relatively warm winters and therefore a reduced need for space-heating. So much so that only 53% of all HH's mentioned the need for space-heating, of which most use paraffin. Since Pietermaritzburg is situated at a higher altitude there is a greater need for space-heating, with about 27% of HH's using wood for this purpose. They are also situated quite far from coal mines which makes coal prohibitively expensive for the poorer non-electrified HH's. This is reflected in the energy consumption patterns depicted by Table 3. The area represents approximately 0.3 million HH's, but specific data on the number of electrified vs non-electrified is not available.

Coal dominates as an alternative for electrified HH's. As can be seen from Fig.6 and Table 2, 21% of electrified HH's still use coal, while 74% use electricity as their sole energy-carrier. It is also clear that a very small minority of the electrified HH's use any other type of fuel. An interesting observation is that paraffin appliances do not constitute a major investment, unlike coal stoves. Hence, it is found that as soon as electricity is supplied very few HH's continue using paraffin, but that this is not the case with coal. It also indicates that electricity can compete with paraffin and other fuels on the basis of cost.

The conclusion is therefore that  $S(DFR)=74%$  with the switch being mainly away from paraffin and with those that do not switch to electricity mainly using coal as an alternative due to the capital barrier posed by the investment in coal stoves, and the seeming lack of a secondary market for coal stoves.

### 2.1.3. Cape Town

Paraffin and LPG dominate as alternative fuel sources in the Cape Town area. That can probably be attributed to the lack of proximity of coal mines leading to prohibitive costs for coal. Similar to the DFR region, once electrified, HH's switch completely from paraffin or LPG to electricity, hence as can be seen from Table 4, practically no other fuels are consumed as an alternative to electricity by the electrified HH's. It confirms that coal stoves represent a capital barrier to electrification, while paraffin does not.

Hence,  $S(\text{Cape Town})=90\%$ , with the switch being away from paraffin and LPG.

### 2.1.4. Eastern Cape (PE & EL)

Table 5 indicates that the fuel consumption patterns are similar to Cape Town. Paraffin dominates among the non-electrified HH's, with electrification resulting in a 72% switch to electricity as sole energy-carrier. Due to the large numbers of paraffin users to start off with, one can expect that some HH will not switch to electricity. Care must be taken not to confuse fuel being used as a backup for electricity (due to the high incidence of electricity supply failure) with fuel being used as sole energy-carrier.

In other words,  $S(\text{PE\&EL})=72\%$ , with the switch being away from paraffin.

### 2.1.5. Orange Free State(OFS)

The OFS is classified as a secondary urban area of South Africa. This category represents 530000 HH's. Data on the number of HH's in the OFS region is not available. The monthly delivered energy figures must therefore be used.

As can be seen from Table 6, 77% of the electrified HH's use electricity as their main energy-carrier. However, this seems to contradict Simon and Norval (EDRC,1993) who found that 70% of electrified HH's in Mangaung outside Bloemfontein owned coal stoves. This study predates the energy consumption figures and therefore its results will be ignored here. However, it does place an additional question mark over data on the OFS region. That is additional to the concern about the accuracy of the data evoked by the large number of users found switching away from coal to electricity and given our previous comments about the capital barrier represented by coalstoves.

It is therefore concluded that about 77% of electrified HH's have switched away from coal to electricity as sole energy-carrier in the OFS. In other words  $S(\text{OFS})=77\%$ .

Data on other urban areas which consist mainly of towns and closer settlements is simply too sparse to draw any clear conclusions. Results from the regions analyzed above will therefore be applied to the rest of urban South Africa.

## **2.2. Modelling expected electricity use in the rural areas of South Africa.**

As clarified earlier, Kimberley will be classified as a rural area and its electrified HH's used as a model for predicting the behaviour of the currently non-electrified HH's both in Kimberley and in the other rural areas of South Africa which consist mainly of the "homelands/self-governing states" as well as farmworker HH's.

### **2.2.1. Kimberley**

The area suffers from severe winters and is also situated quite far from any coal mines. This implies that there is a definite need for space-heating together with a relatively high price for coal (40c/kg vs 20c-30c/kg in PWV). Some non-electrified HH's are therefore using paraffin for space-heating purposes due to the high cost of coal. This is reflected in the monthly delivered energy figures (See Table 7 & Fig. 6).

There were only 9000 electrified HH's in Kimberley at the time of this study. From Table 7 it can be seen that 35% of electrified HH's still use coal. Again it is clear that paraffin users switch to electricity to a far greater extent than do coal users. The same also seems to hold for wood users. If the conclusions drawn about the PWV HH's are applied to Kimberley it may be concluded that 35% of the electrified HH's (3150 HH's) are still using coal stoves for cooking, space heating and water heating purposes. 48% of the remaining 65% (5850 HH's) only use electricity. The others may be using paraffin, candles and wood for a very limited number of end-uses.

It may therefore be concluded that  $S(\text{Kimberley})=0.48$ , with the switch being away from wood and paraffin.

### **2.2.2. The homelands/self-governing states<sup>4</sup>**

The rural "homelands" of South Africa comprise approximately 2 162 000 HH's. Currently the "homelands" may be characterised by an almost total lack of access to electricity. As Table 8 shows, wood dominates as energy carrier in these areas, except perhaps for QwaQwa, where proximity to a coal mine makes coal a more affordable energy carrier than wood. Switching in the homelands can therefore be expected to be away from wood, not coal or paraffin, to

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<sup>4</sup> See table 8 for a specification of the areas included under this category.

electricity, as was the case in Kimberley and most of the urban areas of South Africa. What difference does this make to the conclusions that are drawn and the expected extent of the switch to electricity ?

Based on the discussion of the urban situation, the chief barriers to total switching in the areas where coal dominated as energy carrier was the weather patterns, ie. the need for space-heating, but more importantly, the capital barrier presented by a coal stove due to the lack of a secondary market. It was found that this explained why paraffin dominated areas switched to electricity to a far greater extent due to the absence of this capital barrier. Most wood fires made in rural areas require no initial capital outlay. This should therefore imply an extensive switch to electricity. On the other hand, the price of wood in these rural areas must often be measured in terms of income foregone during collection since it is obtained free of charge. Due to the low wages in these parts, this represents a very low price for wood. Also, due to the lack of infrastructure, electricity provision will be accompanied by extensive capital outlays which will be recouped via higher electricity costs. This being the case, it is clear that determining exactly to what extent rural HH's will switch to electricity as their sole energy carrier is by no means an easy exercise.

This short diversion has revealed the multitude of complexities involved in making predictions about expected electricity use. The most appropriate option remains to use the best model of expected behaviour for rural HH's, namely Kimberley. From the analysis of Kimberley's HH's it was clear that 48% are expected to switch to electricity as their sole energy-carrier once access to electricity has been provided. Applying this result to energy consumption data (Tables 9-12) for the "homelands" implies that it can be expected that 48% of the HH's in the "homelands" will switch to electricity as their sole energy-carrier once they have access to it.

A complicating factor however is the disparity that exists between the results of different studies in terms of energy consumption in the rural areas. This is quite reasonable given the nature of these areas and the difficulties that this holds for fieldworkers. However, clarification of some of the disparities is necessary.

An examination of Tables 8 to 11 reveals wood dominating as energy carrier in some of the rural areas. Energy consumption figures in terms of megajoules delivered per month are only available for four areas, namely Namaqualand, Bophuthatswana, Gazankulu and Transkei and Ciskei combined. The disparity emerges when these figures are translated into percentage megajoules contributed to total energy consumption by each fuel and compared to those of Table 8, which come from a different group of studies. A common trend is that the role of wood is overstated in Table 8 when compared to Tables 9 to 12. However, if the percentage contributed by dung is added to that contributed by wood in Tables 9 to 12, very similar results to those reported in Table 8 are obtained, which does not report dung consumption figures. It must be inferred that the studies on which Table 8 are based were less refined and dung was included under wood consumption.

Given this analysis, it is now possible to draw some qualitative conclusions about energy consumption in the other areas reported in Table 8, but not reported in Tables 9 to 12, ie. for which detailed data does not exist. Firstly, according to Table 8, Venda and Gazankulu have exactly the same energy consumption patterns. Hence it should be possible to simply duplicate Gazankulu's results for Venda. Secondly, KaNgwane and Lebowa have exactly the same consumption patterns as well and they do not differ significantly from Gazankulu's and Venda's energy consumption patterns. So Gazankulu's results may also be duplicated for these areas. KwaNdebele, KwaZulu and QwaQwa have quite unique consumption patterns, and therefore not much more can be said about them. Similar consumption patterns is by no means a reflection of a similar socio-economic environment. Very different factors could cause the HH's in two different areas to behave in the same way. That does not mean though that, were these two areas to be electrified, they would continue behaving in the same way. Such an assumption can only be made about areas with similar socio-economic environments.

Tables 9 to 12 summarise the energy consumption patterns and their implications in terms of air pollution production for Namaqualand, Bophuthatswana, Gazankulu, Venda, KaNgwane, Lebowa and the Transkei and Ciskei.

### **2.2.3. Farmworkers:**

The next category of rural HH's is farmworkers. Data is much more readily available for this category, although similar problems with study methodology and the fact that very often farm owners supplied data on behalf of workers also places a question mark over data in this category.

There are approximately 879 000 farmworker HH's in South Africa. From a cross-section of studies performed on farmworkers, it becomes clear that between 22% and 32% of all worker HH's have access to electricity. This stands in contrast to the approximately 68% of farms that have access to electricity nationally. Furthermore, as can be seen from Table 13, on average only 3% of farmworker HH's nationally use electricity for cooking and heating, and 18% use it for lighting.

Several conclusions can be drawn from Tables 13 and 14. Firstly, paraffin and candles seem to be the main sources of light for farmworker HH's. However, due to the minimal capital outlay required to use electricity for lighting once it is provided, candle and paraffin consumption decreases significantly once access to electricity is provided, as Table 14 shows. The same cannot be said for cooking and space heating. Fuelwood dominates as a source of cooking and space heating. This is an energy source requiring very little capital outlay. Furthermore, due to the geographical position of most farms, fuelwood is very accessible, making it cheap and easy to use. Looking at Table 14 it is then not surprising that when electricity is provided, fuelwood consumption does not decrease significantly, and even amongst the electrified

farmworker HH's, 85% still use fuelwood. This result is obvious if it is borne in mind that were electricity to be used for cooking and space-heating, electrical appliances are required, which is not the case for fuelwood. Since fuelwood used for cooking and space-heating is the major source of air-pollution when compared with candles and paraffin used for lighting, it is clear that the health impact of electrification on farmworkers will be very insignificant. Based on the data at hand, it seems that as little as 6% of electrified farmworker HH's will switch to total electricity use once access is provided. This category will therefore not be analyzed any further in the rest of this thesis.

Table A below summarises these results, indicating, for both urban and rural HH's, the expected switch to electricity as sole energy-carrier once supply has been effected.

Area	% HH's expected to switch to electricity as their sole energy-carrier.	Switch away from which fuel ?
<u>Urban:</u>		
PWV	54%	Coal
DFR & Pietermaritzburg	74%	Paraffin
Cape Town	90%	LPG & Paraffin
PE & EL	72%	Paraffin
OFS	77%	Coal
<u>Rural:</u>		
Kimberley	48%	Paraffin
Namaqualand	48%	Wood
Bophuthatswana	48%	Wood
Gazankulu, Venda, KaNgwane & Lebowa	48%	Wood
Transkei/Ciskei	48%	Wood

Table A : Predicted substitution of electricity for other fuels. (Source : EDRC,1993)

## Chapter 3. The health benefits of electrification

This chapter translates the results of the previous analysis into health benefits.

### 3.1. Respiratory infections

Table A reports the percentage of currently non-electrified HH's expected to switch to electricity as their sole energy-carrier once they gain access to it. This section shows the impact that this will have on the number of respiratory infection cases in SA using the methodology outlined in part 1 of section 2 of chapter 1. Table 17 contains the details and Table B a summary of this calculation, and shows an average national reduction of 76.45% in morbidity due to respiratory infections.

One may proceed slightly further along the cross-disciplinary path and also calculate the elasticity of mortality and morbidity with respect to air pollution. It entails translating the  $10\mu\text{gm}^3$  increase in air pollution mentioned above into a percentage increase. This will show whether mortality and morbidity is elastic or inelastic with respect to air pollution. This gives an indication of the responsiveness of mortality and morbidity to air pollution. It shows the percentage change in mortality and morbidity for a 1% change in air pollution. An elasticity less than 1 is said to be inelastic, while an elasticity greater than 1 is said to be elastic. Table 17 also contains this information.

### 3.2. Paraffin poisoning

Table 18 shows the expected percentage change in paraffin use by region after electrification, using the methodology outlined before. Employing the 1/3, 2/3 split between electrified and non-electrified HH's in those areas where specific data is not available, it is possible to calculate the expected change in HH paraffin use measured in millions of litres, based on a conversion of 1 litre of paraffin = 0.8 kg's of paraffin. Table 18 shows the results of this calculation. Finally, applying the information supplied by Yach (in press) mentioned before, it is possible to calculate the expected change in number of hospitalised paraffin poison cases by area. Table 18 shows that due to a lack of data, the calculations could not be completed for the OFS and the rural areas of South Africa. This is because the total number of HH's in these areas is not known. However, it is found that a total reduction of 4899 paraffin poisoning cases can be expected from the urban areas once they are provided with electricity. Table C below summarises these results.

Area	% change in morbidity due to respiratory infections.
<u>Urban:</u>	
PWV	-46.50%
DFR & Pietermaritzburg	-48.92%
Cape Town	-83.80%
PE & EL	-63.46%
OFS	-142.78%
<u>Rural:</u>	
Kimberley	-24.56%
Namaqualand	-85.40%
Bophuthatswana	-88.52%
Gazankulu, Venda, KaNgwane & Lebowa	-90.49%
Transkei/Ciskei	-90.04%
Average	-76.45%

**Table B : The impact of electrification on respiratory infection morbidity.**

**Table 17 : Predicted substitution of electricity for other fuels  
and its health implications due to reduced air pollution.**

Area	Percentage of HH's expected to switch to electricity as sole energy-carrier	Switch away from which fuel ?	Percentage change in HH air pollution	Current exposure levels (micrograms/cubic meter)	Change in exposure levels (micrograms/cubic meter)	Percentage change in mortality levels	Elasticity of mortality with respect to air pollution	Percentage change in morbidity levels	Elasticity of morbidity with respect to air pollution
<b>URBAN:</b>									
PWV	54.00	Coal	-23.25	1000.00	-232.51	-23.25	1.00	-46.50	2.00
DFR & Pietermaritzburg	74.00	Paraffin	-48.92	500.00	-244.60	-24.46	0.50	-48.92	1.00
Cape Town	90.00	LPG & Paraffin	-63.80	500.00	-418.99	-41.90	0.50	-63.80	1.00
PE & EL	72.00	Paraffin	-63.46	500.00	-317.28	-31.73	0.50	-63.46	1.00
OFS	77.00	Coal	-71.39	1000.00	-713.91	-71.39	1.00	-142.78	2.00
<b>RURAL:</b>									
Kimberley	48.00	Paraffin	-24.56	500.00	-122.81	-12.28	0.50	-24.56	1.00
Namaqualand	48.00	Wood	-42.70	1000.00	-427.02	-42.70	1.00	-85.40	2.00
Bophuthatswana	48.00	Wood	-44.26	1000.00	-442.61	-44.26	1.00	-88.52	2.00
Gezankulu, Venda, KaNgwane and Lebowa	48.00	Wood	-45.25	1000.00	-452.47	-45.25	1.00	-90.49	2.00
Transkei/Ciskei	48.00	Wood	-45.02	1000.00	-450.21	-45.02	1.00	-90.04	2.00

(Sources : EDRC,1993;Ozkaynak,1993)

**Table 18 : Predicted substitution of electricity for other fuels  
and its health implications due to reduced paraffin poisoning.**

Area	Percentage of HH's expected to switch to electricity as sole energy-carrier	Percentage change in paraffin use per household once electrified	Change in paraffin use (millions of litres)	Change in number of paraffin poison cases
<b>URBAN:</b>				
PWV	54.00	12.61	-1.55	-46.44
DFR & Pietermaritzburg	74.00	30.97	-2.19	-65.74
Cape Town	90.00	47.57	-1.08	-32.51
PE & EL	72.00	49.03	-2.22	-66.71
OFS	77.00	37.09	Insufficient data	
<b>RURAL:</b>				
Kimberley	48.00	7.59	Insufficient data	
Namaqualand	48.00	23.85	Insufficient data	
Bophuthatswana	48.00	1.29	Insufficient data	
Gazankulu , Venda, KaNgwane and Lebowa	48.00	0.87	Insufficient data	
Transkei/Ciskei	48.00	-0.33	Insufficient data	

(Sources : EDRC, 1983; Yach, in press)

Area	Change in HH paraffin sold (millions of litres)	Change in number of paraffin poisonings
<u>Urban:</u>		
PWV	-79.54	-2,386.00
DFR & Pietermaritzburg	-41.25	-1,237.00
Cape Town	-16.40	-492.00
PE & EL	-26.12	-784.00
<u>Total :</u>	-163.31	-4,899.00

Table C : The impact of electrification on paraffin poisonings.

### 3.3. Burns

Tables 19a-c report the impact of electrification on burns, using the methodology outlined before. The Tables differ in that they utilise different fatality-case-ratios, ranging from 65.79 to 92.59. The benefit of electrification in terms of a reduced number of burn cases is calculated by subtracting the post-electrification from the pre-electrification burn figure. It can be seen from Table 19b (the most conservative estimate) that an average of 35065 fewer burn cases can be expected after electrification. Table D summarises these results.

	<b>FCR=65.79</b>	<b>FCR=78.75</b>	<b>FCR=92.59</b>
<b>Total benefit using 'Census' method</b>	19002	22745	26742
<b>Total benefit using 'Calculated' method</b>	51128	61199	71955
<b>Average benefit</b>	<b>35065</b>	41972	49348.5

Table D : Summary of impact of electrification on burns.

In summary, the switch to total electricity use by newly-electrified areas results in a 76.45% reduction in respiratory infections, 4899 fewer paraffin poisonings, and 35065 fewer burns. The next section is an attempt to quantify the health benefits of electrification.

Table 19a : Analysis of effect of electrification on burn cases (FCR=78.75)

	Whites		Coloureds		Asians		Blacks		Total benefit	
	Census	Calculated	Census	Calculated	Census	Calculated	Census	Calculated	Census	Calculated
<b>&lt; 1 Year old</b>										
Population size	83732.00	83732.00	88980.00	88980.00	16834.00	16834.00	519284.00	519284.00		
Mortality rate (per 1000)	9.37	9.00	43.51	48.45	12.71	15.85	23.01	70.50		
Total number of deaths	597.00	573.59	3049.00	3245.67	214.00	269.50	11949.00	36908.11		
% due to burns	0.00	0.00	0.10	0.10	0.00	0.00	0.13	0.13		
Number of deaths due to burns	0.00	0.00	3.00	3.19	0.00	0.00	16.00	48.02		
Burn mortality rate (per 1000)	0.00	0.00	0.04	0.05	0.00	0.00	0.03	0.09		
Fatality-case ratio	78.75	78.75	78.75	78.75	78.75	78.75	78.75	78.75		
No. of cases	0.00	0.00	236.25	251.49	0.00	0.00	1280.00	3660.26		
After electrification	0.00	0.00	73.24	77.98	0.00	0.00	390.60	1186.88		
Benefit (reduced no. of cases)	0.00	0.00	163.01	173.53	0.00	0.00	889.40	2663.38	1032.41	2637.10
<b>1-4 years old</b>										
Population size	284099.00	284099.00	303323.00	303323.00	81523.00	81523.00	2482795.00	2482795.00		
Mortality rate (per 1000)	0.88	0.88	2.40	4.19	0.69	1.14	1.38	7.00		
Total number of deaths	243.00	248.59	729.00	1270.17	56.00	92.73	3370.00	17378.57		
% due to burns	1.23	1.23	2.08	2.08	3.57	3.57	1.54	1.54		
Number of deaths due to burns	3.00	3.07	15.00	26.14	2.00	3.31	52.00	268.17		
Burn mortality rate (per 1000)	0.01	0.01	0.05	0.09	0.02	0.04	0.02	0.11		
Fatality-case ratio	78.75	78.75	78.75	78.75	78.75	78.75	78.75	78.75		
No. of cases	236.25	241.68	1181.25	2056.14	157.50	260.81	4095.00	21118.48		
After electrification	236.25	241.68	540.23	816.07	85.60	128.70	2894.05	8004.08		
Benefit (reduced no. of cases)	0.00	0.00	641.02	1242.07	61.90	132.11	1400.95	13114.41	2103.67	14488.59
<b>5-14 years old</b>										
Population size	773735.00	773735.00	729882.00	729882.00	202589.00	202589.00	5197807.00	5197807.00		
Mortality rate (per 1000)	0.31	0.31	0.58	0.70	0.32	0.43	0.34	0.94		
Total number of deaths	242.00	239.86	410.00	510.22	65.00	87.11	1752.00	4885.94		
% due to burns	0.41	0.41	1.46	1.46	1.54	1.54	1.83	1.83		
Number of deaths due to burns	1.00	0.99	6.00	7.47	1.00	1.34	32.00	89.24		
Burn mortality rate (per 1000)	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02		
Fatality-case ratio	78.75	78.75	78.75	78.75	78.75	78.75	78.75	78.75		
No. of cases	78.75	78.05	472.50	567.99	78.75	105.54	2320.00	7027.72		
After electrification	78.75	78.05	197.96	233.01	36.84	46.82	1148.22	2540.39		
Benefit (reduced no. of cases)	0.00	0.00	274.54	334.98	40.11	58.72	1373.78	4487.33	1686.73	4901.03
<b>15-44 years old</b>										
Population size	2445431.00	2445431.00	1894824.00	1894824.00	501874.00	501874.00	10253493.00	10253493.00		
Mortality rate (per 1000)	1.48	1.73	3.48	4.20	1.71	2.39	2.03	4.99		
Total number of deaths	3623.00	4218.37	5899.00	7118.26	859.00	1199.46	20883.00	51164.83		
% due to burns	0.38	0.38	0.68	0.68	0.93	0.93	1.04	1.04		
Number of deaths due to burns	13.00	15.14	40.00	48.27	8.00	11.17	217.00	532.18		
Burn mortality rate (per 1000)	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.05		
Fatality-case ratio	78.75	78.75	78.75	78.75	78.75	78.75	78.75	78.75		
No. of cases	1023.75	1191.98	3150.00	3801.07	630.00	878.71	17088.75	41808.67		
After electrification	1023.75	1191.98	1468.07	1748.35	340.27	441.50	8259.34	18440.29		
Benefit (reduced no. of cases)	0.00	0.00	1681.93	2052.72	289.73	438.21	8829.41	25468.56	10803.07	27859.50

Table 19a : Analysis of effect of electrification on burn cases (FCR=78.75)(Continued)

45-64 years old									
Population size	1026389.00	1026389.00	378797.00	378797.00	148970.00	148970.00	2482847.00	2482847.00	
Mortality rate (per 1000)	7.14	10.33	18.71	17.32	10.35	15.46	9.22	18.47	
Total number of deaths	7332.00	10602.80	7107.00	6578.06	1532.00	2318.34	22891.00	45654.48	
% due to burns	0.18	0.18	0.34	0.34	0.13	0.13	0.35	0.35	
Number of deaths due to burns	12.00	17.35	24.00	22.21	2.00	2.89	81.00	162.26	
Burn mortality rate (per 1000)	0.01	0.02	0.06	0.06	0.01	0.02	0.03	0.07	
Fatality-case ratio	78.75	78.75	78.75	78.75	78.75	78.75	78.75	78.75	
No. of cases	945.00	1368.54	1890.00	1748.34	197.30	235.29	6378.75	12777.70	
After electrification	945.00	1368.54	827.18	891.20	144.10	210.71	3554.80	8241.82	
Benefit (reduced no. of cases)	0.00	0.00	1062.82	856.14	13.40	24.58	2824.15	6535.88	3900.37 7418.80
65-84 years old									
Population size	474705.00	474705.00	111801.00	111801.00	33831.00	33831.00	710463.00	710463.00	
Mortality rate (per 1000)	35.84	35.28	58.52	38.18	38.88	39.38	30.81	40.20	
Total number of deaths	17058.00	16747.38	6549.00	4272.38	1308.00	1332.26	21892.00	28360.61	
% due to burns	0.01	0.01	0.28	0.28	0.15	0.15	0.19	0.19	
Number of deaths due to burns	1.00	0.98	17.00	11.09	2.00	2.04	42.00	54.79	
Burn mortality rate (per 1000)	0.00	0.00	0.15	0.10	0.08	0.08	0.08	0.08	
Fatality-case ratio	78.75	78.75	78.75	78.75	78.75	78.75	78.75	78.75	
No. of cases	78.75	77.31	1338.75	873.38	157.30	180.42	3307.50	4315.01	
After electrification	78.75	77.31	427.82	283.32	52.70	33.53	1108.65	1417.48	
Benefit (reduced no. of cases)	0.00	0.00	910.93	590.04	104.80	108.89	2200.85	2897.52	3218.58 3394.45
<b>Total Benefit</b>									22745.04 81189.28

(Sources : Census,1991;Bradshaw et al,1992;Abraham,1994)

Table 19b : Analysis of effect of electrification on burn cases (FCR=65.79)

	Whites		Coloureds		Asians		Blacks		Total benefit	
	Census	Calculated	Census	Calculated	Census	Calculated	Census	Calculated	Census	Calculated
<b>&lt; 1 Year old</b>										
Population size	63732.00	63732.00	66980.00	66980.00	16834.00	16834.00	519264.00	519264.00		
Mortality rate (per 1000)	9.37	9.00	45.51	46.45	12.71	13.95	23.01	70.50		
Total number of deaths	597.00	573.59	3049.00	3245.67	214.00	266.50	11949.00	36808.11		
% due to burns	0.00	0.00	0.10	0.10	0.00	0.00	0.13	0.13		
Number of deaths due to burns	0.00	0.00	3.00	3.19	0.00	0.00	16.00	49.02		
Burn mortality rate (per 1000)	0.00	0.00	0.04	0.05	0.00	0.00	0.03	0.09		
Fatality-case ratio	65.79	65.79	65.79	65.79	65.79	65.79	65.79	65.79		
No. of cases	0.00	0.00	197.37	210.10	0.00	0.00	1052.84	3224.87		
After electrification	0.00	0.00	61.18	65.13	0.00	0.00	326.32	969.74		
Benefit (reduced no. of cases)	0.00	0.00	136.19	144.87	0.00	0.00	726.32	2225.23	962.51	2370.20
<b>1-4 years old</b>										
Population size	264098.00	264098.00	303323.00	303323.00	81523.00	81523.00	2462795.00	2462795.00		
Mortality rate (per 1000)	0.88	0.88	2.40	4.19	0.89	1.14	1.38	7.00		
Total number of deaths	243.00	246.59	729.00	1270.17	58.00	82.73	3370.00	17379.57		
% due to burns	1.23	1.23	2.06	2.06	3.57	3.57	1.54	1.54		
Number of deaths due to burns	3.00	3.07	15.00	26.14	2.00	3.31	52.00	268.17		
Burn mortality rate (per 1000)	0.01	0.01	0.05	0.09	0.02	0.04	0.02	0.11		
Fatality-case ratio	65.79	65.79	65.79	65.79	65.79	65.79	65.79	65.79		
No. of cases	197.37	201.81	986.65	1719.43	131.56	217.89	3421.08	17842.99		
After electrification	197.37	201.81	451.32	681.77	79.87	107.52	2250.68	6886.94		
Benefit (reduced no. of cases)	0.00	0.00	535.33	1037.66	51.71	110.37	1170.40	10856.15	1757.63	12104.18
<b>5-14 years old</b>										
Population size	773758.00	773758.00	726682.00	726682.00	202569.00	202569.00	5197807.00	5197807.00		
Mortality rate (per 1000)	0.31	0.31	0.56	0.70	0.32	0.43	0.34	0.84		
Total number of deaths	242.00	239.86	410.00	510.22	65.00	87.11	1732.00	4685.94		
% due to burns	0.41	0.41	1.46	1.46	1.54	1.54	1.63	1.63		
Number of deaths due to burns	1.00	0.99	6.00	7.47	1.00	1.34	32.00	89.24		
Burn mortality rate (per 1000)	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02		
Fatality-case ratio	65.79	65.79	65.79	65.79	65.79	65.79	65.79	65.79		
No. of cases	65.79	65.21	394.74	491.23	65.79	66.17	2105.28	5671.16		
After electrification	65.79	65.21	165.13	194.87	32.28	39.11	857.56	2122.32		
Benefit (reduced no. of cases)	0.00	0.00	229.61	296.56	33.51	49.06	1147.70	3748.84	1410.81	4094.46
<b>15-44 years old</b>										
Population size	2445431.00	2445431.00	1894824.00	1894824.00	501874.00	501874.00	10233483.00	10233483.00		
Mortality rate (per 1000)	1.48	1.73	3.48	4.20	1.71	2.39	2.03	4.89		
Total number of deaths	3623.00	4218.37	5699.00	7119.26	859.00	1199.46	20863.00	51184.83		
% due to burns	0.36	0.36	0.68	0.68	0.83	0.83	1.04	1.04		
Number of deaths due to burns	13.00	15.14	40.00	48.27	8.00	11.17	217.00	532.16		
Burn mortality rate (per 1000)	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.05		
Fatality-case ratio	65.79	65.79	65.79	65.79	65.79	65.79	65.79	65.79		
No. of cases	855.27	995.82	2831.60	3175.32	526.32	734.94	14278.43	35011.67		
After electrification	855.27	995.82	1224.79	1460.62	294.27	368.65	8900.09	13734.69		
Benefit (reduced no. of cases)	0.00	0.00	1406.81	1714.80	242.05	366.09	7378.34	21277.18	9025.20	23356.17

Table 19b : Analysis of effect of electrification on burn cases (FCR=65.79) (Continued)

45-64 years old										
Population size	1026369.00	1026369.00	379797.00	379797.00	149970.00	149970.00	2482947.00	2482947.00		
Mortality rate (per 1000)	7.14	10.33	18.71	17.32	10.35	13.48	9.22	18.47		
Total number of deaths	7332.00	10602.60	7107.00	6576.08	1552.00	2319.54	22891.00	45854.48		
% due to burns	0.18	0.18	0.34	0.34	0.13	0.13	0.35	0.35		
Number of deaths due to burns	12.00	17.35	24.00	22.21	2.00	2.98	81.00	162.26		
Burn mortality rate (per 1000)	0.01	0.02	0.06	0.06	0.01	0.02	0.03	0.07		
Fatality-case ratio	65.79	65.79	65.79	65.79	65.79	65.79	65.79	65.79		
No. of cases	788.48	1141.84	1378.96	1461.45	131.58	198.57	5328.88	10674.86		
After electrification	788.48	1141.84	891.05	744.54	120.38	178.04	2989.82	3214.58		
Benefit (reduced no. of cases)	0.00	0.00	867.81	716.91	11.20	20.53	2339.07	5460.28	3258.48	6197.71
65-84 years old										
Population size	474705.00	474705.00	111801.00	111801.00	33831.00	33831.00	710463.00	710463.00		
Mortality rate (per 1000)	35.84	35.28	58.52	38.18	38.88	39.38	30.81	40.20		
Total number of deaths	17059.00	16747.58	6548.00	4272.38	1308.00	1332.28	21892.00	28580.81		
% due to burns	0.01	0.01	0.28	0.28	0.15	0.15	0.19	0.19		
Number of deaths due to burns	1.00	0.88	17.00	11.08	2.00	2.04	42.00	54.79		
Burn mortality rate (per 1000)	0.00	0.00	0.15	0.10	0.06	0.06	0.06	0.08		
Fatality-case ratio	65.79	65.79	65.79	65.79	65.79	65.79	65.79	65.79		
No. of cases	65.79	84.58	1118.43	728.63	131.58	134.02	2783.18	3604.88		
After electrification	65.79	84.58	337.41	238.69	44.02	44.72	824.53	1184.21		
Benefit (reduced no. of cases)	0.00	0.00	781.02	489.94	87.56	89.30	1858.65	2420.67	2867.22	3002.91
<b>Total Benefit</b>									19001.86	51127.63

(Sources : Census, 1991; Bradshaw et al, 1992; Abrahams, 1994)

Table 19c : Analysis of effect of electrification on burn cases (FCR=92.59)

	Whites		Coloureds		Asians		Blacks		Total benefit	
	Census	Calculated	Census	Calculated	Census	Calculated	Census	Calculated	Census	Calculated
<b>&lt; 1 Year old</b>										
Population size	63732.00	63732.00	66990.00	66990.00	18834.00	18834.00	519284.00	519284.00		
Mortality rate (per 1000)	9.37	9.00	45.51	48.45	12.71	15.95	23.01	70.50		
Total number of deaths	567.00	573.59	3049.00	3245.87	214.00	288.50	11949.00	36808.11		
% due to burns	0.00	0.00	0.10	0.10	0.00	0.00	0.13	0.13		
Number of deaths due to burns	0.00	0.00	3.00	3.19	0.00	0.00	16.00	48.02		
Burn mortality rate (per 1000)	0.00	0.00	0.04	0.05	0.00	0.00	0.03	0.09		
Fatality-case ratio	92.59	92.59	92.59	92.59	92.59	92.59	92.59	92.59		
No. of cases	0.00	0.00	277.77	295.69	0.00	0.00	1481.44	4538.68		
After electrification	0.00	0.00	86.11	81.88	0.00	0.00	458.25	1406.99		
Benefit (reduced no. of cases)	0.00	0.00	191.66	204.02	0.00	0.00	1022.19	3131.69	1213.85	3335.71
<b>1-4 years old</b>										
Population size	284099.00	284099.00	303323.00	303323.00	81923.00	81923.00	2482795.00	2482795.00		
Mortality rate (per 1000)	0.96	0.96	2.40	4.19	0.89	1.14	1.38	7.00		
Total number of deaths	243.00	248.59	728.00	1270.17	58.00	92.73	3370.00	17379.57		
% due to burns	1.23	1.23	2.06	2.06	3.57	3.57	1.54	1.54		
Number of deaths due to burns	3.00	3.07	15.00	26.14	2.00	3.31	52.00	268.17		
Burn mortality rate (per 1000)	0.01	0.01	0.05	0.09	0.02	0.04	0.02	0.11		
Fatality-case ratio	92.59	92.59	92.59	92.59	92.59	92.59	92.59	92.59		
No. of cases	277.77	284.16	1388.85	2419.85	185.18	308.85	4814.88	24829.98		
After electrification	277.77	284.16	635.17	959.48	112.40	151.32	3187.52	9410.77		
Benefit (reduced no. of cases)	0.00	0.00	753.68	1480.38	72.78	155.32	1647.16	15419.22	2473.82	17034.80
<b>5-14 years old</b>										
Population size	773735.00	773735.00	728882.00	728882.00	202569.00	202569.00	5197807.00	5197807.00		
Mortality rate (per 1000)	0.31	0.31	0.56	0.70	0.32	0.43	0.34	0.94		
Total number of deaths	242.00	239.88	410.00	510.22	85.00	87.11	1732.00	4885.94		
% due to burns	0.41	0.41	1.48	1.48	1.54	1.54	1.83	1.83		
Number of deaths due to burns	1.00	0.99	6.00	7.47	1.00	1.34	32.00	89.24		
Burn mortality rate (per 1000)	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02		
Fatality-case ratio	92.59	92.59	92.59	92.59	92.59	92.59	92.59	92.59		
No. of cases	92.59	91.77	555.54	691.33	92.59	124.09	2982.88	6282.81		
After electrification	92.59	91.77	232.40	273.98	45.43	55.05	1347.88	2988.85		
Benefit (reduced no. of cases)	0.00	0.00	323.14	417.37	47.16	69.04	1615.22	3275.96	1985.52	5782.37
<b>15-44 years old</b>										
Population size	2445431.00	2445431.00	1694824.00	1694824.00	501874.00	501874.00	10253483.00	10253483.00		
Mortality rate (per 1000)	1.48	1.73	3.48	4.20	1.71	2.39	2.03	4.89		
Total number of deaths	3623.00	4218.37	5899.00	7118.26	859.00	1199.48	20863.00	51184.83		
% due to burns	0.36	0.36	0.68	0.69	0.93	0.93	1.04	1.04		
Number of deaths due to burns	13.00	15.14	40.00	48.27	8.00	11.17	217.00	532.18		
Burn mortality rate (per 1000)	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.05		
Fatality-case ratio	92.59	92.59	92.59	92.59	92.59	92.59	92.59	92.59		
No. of cases	1203.87	1401.47	3703.80	4469.09	740.72	1034.32	20092.03	49274.18		
After electrification	1203.87	1401.47	1723.72	2055.82	400.07	519.10	9710.88	19329.81		
Benefit (reduced no. of cases)	0.00	0.00	1979.88	2413.48	340.65	515.22	10381.15	29944.38	12701.87	32873.28

Table 19c : Analysis of effect of electrification on burn cases (FCR=92.59) (Continued)

45-64 years old										
Population size	1026369.00	1026369.00	379797.00	379797.00	149970.00	149970.00	2482947.00	2482947.00		
Mortality rate (per 1000)	7.14	10.33	18.71	17.32	10.35	15.46	9.22	18.47		
Total number of deaths	7332.00	10602.60	7107.00	6578.08	1532.00	2318.54	22891.00	45654.49		
% due to burns	0.18	0.18	0.34	0.34	0.13	0.13	0.35	0.35		
Number of deaths due to burns	12.00	17.35	24.00	22.21	2.00	2.89	81.00	162.26		
Burn mortality rate (per 1000)	0.01	0.02	0.08	0.08	0.01	0.02	0.03	0.07		
Fatality-case ratio	92.59	92.59	92.59	92.59	92.59	92.59	92.59	92.59		
No. of cases	1111.08	1808.70	2222.18	2056.78	185.18	278.64	7489.79	15023.33		
After electrification	1111.08	1808.70	972.55	1047.83	189.42	247.74	4179.31	7338.79		
Benefit (reduced no. of cases)	0.00	0.00	1249.61	1008.95	15.78	28.90	3320.48	7684.54	4583.94	8722.39
65-84 years old										
Population size	474705.00	474705.00	111801.00	111801.00	33831.00	33831.00	710463.00	710463.00		
Mortality rate (per 1000)	35.94	35.28	58.52	38.18	38.88	39.38	30.81	40.20		
Total number of deaths	17059.00	16747.58	6549.00	4272.38	1308.00	1332.28	21892.00	28560.61		
% due to burns	0.01	0.01	0.28	0.28	0.15	0.15	0.19	0.19		
Number of deaths due to burns	1.00	0.88	17.00	11.09	2.00	2.04	42.00	54.79		
Burn mortality rate (per 1000)	0.00	0.00	0.15	0.10	0.08	0.08	0.08	0.08		
Fatality-case ratio	92.59	92.59	92.59	92.59	92.59	92.59	92.59	92.59		
No. of cases	92.59	90.90	1574.03	1028.85	185.18	188.82	3888.78	5073.36		
After electrification	92.59	90.90	503.01	333.11	61.98	82.94	1301.14	1888.81		
Benefit (reduced no. of cases)	0.00	0.00	1071.02	693.74	123.22	125.67	2587.64	3408.75	3781.88	4228.18
<b>Total Benefit</b>									28742.30	71854.81

(Sources : Census, 1991; Bradshaw et al, 1992; Abrahams, 1994)

## **Chapter 4. Quantifying the health benefits of electrification.**

This chapter reports the results of the quantification methodology outlined in chapter 1 section 3 used to calculate the economic saving that stems from electrification due to its impact on health.

### **4.1. Respiratory infections.**

Table B summarises the health implications of reduced air pollution. The second to last column shows the percentage change in morbidity due to respiratory infections that can be expected for urban and rural areas of South Africa once they are electrified. Taking a simple average of the figures in this column shows that a reduction of 76.45% in morbidity levels can be expected. This result is used in conjunction with the direct costing methodology outlined above to calculate the economic saving that results from this health 'saving'.

#### **4.1.1. Total cost of transport to GP's**

Table 20 shows that 37.80% of the 32344144 GP contacts are due to blacks, coloureds and Asians (Pestana,1993; Zwarenstein,in press). Of this, 21.21% are due to respiratory infections (Bourne,1991). A 76.45% reduction in respiratory infection morbidity translates into a reduction in GP respiratory infection contacts due to blacks, coloureds and Asians to 8.90%, or a decrease of 1982465.42 cases. This health 'saving' in turn translates into a saving of R 3 203 664 in terms of transportation cost to GP's, using the methodology outline before.

#### **4.1.2. Total cost of transport to Specialists**

Similar to the case described above, the number of Specialist respiratory infection contacts due to blacks, coloureds and Asians decreases by 76.45% to 89533.94. This translates into a saving of R 469 694.65 in terms of the total cost of transportation to specialists.

#### **4.1.3. Total cost of ambulance transportation to hospital**

76.45% fewer blacks, coloureds and Asians can be expected to be transported by ambulance. Before electrification 64% (Note: Remember that hospital discharge figures were used as a proxy for this fraction) of the 7735, or 4950.4 of all the ambulance conveyances of respiratory infections in Cape Town were due to blacks, coloureds and Asians (Pestana - Personal communication 1994). After electrification only 1205.8 ( $4950.4 \times (1-0.7645)$ ) of all Cape Town ambulance conveyances will be due to black, coloured and Asian respiratory infection cases. This translates into a saving at a national level, after the extrapolation to

national figures has been done, of R 6 444 061.47.

#### **4.1.4. Total cost of public & private transport to hospital**

A 76.45% reduction in morbidity due to respiratory infection implies that 76.45% fewer black, coloured and Asian patients will be discharged from hospitals due to the fact that 76.45% fewer of them will go to hospital in the first place. Subtracting the total amount of patients transported by ambulance after electrification as was discussed above from the reduced number of discharges (Census of hospitals, 1990) results in 157367.21 fewer black, coloured and Asian respiratory infection patients that will be using public or private transport to hospital. This translates into a total saving of R 981 971.39.

#### **4.1.5. Total cost of GP consultations**

The impact of the 76.45% reduction in respiratory infections on the number of GP consultations due to blacks, coloureds and Asians was already calculated to be a reduction of 1982465.41. This now also translates into a saving of R 49 205 142.17 in terms of the total cost of GP consultations.

#### **4.1.6. Total cost of Specialist consultations**

Similarly, it was found before that a reduction of 290652.63 in specialist consultations due to black, coloured and Asian respiratory infections can be expected due to electrification. This in turn results in a saving of R 29 065 263.00 in terms of the total cost of specialist consultations.

#### **4.1.7. Total cost of state hospitalisation**

Before electrification black, coloured and Asian respiratory infections constituted 34057 out of a total of 481873 hospital discharges, or 7.07% (Census of hospitals, 1990). The 76.45% reduction in respiratory infection morbidity then means that after electrification this drops to 8020.47 out of a total of 455836.42, or 1.76%. This translates into a saving of R 267 407 648.30 in terms of hospitalisation costs to state hospitals.

#### **Total direct cost saving**

An average reduction in respiratory infection morbidity of 76.45% translates into a total economic direct cost saving of R 356 737 445. Table E summarises these results.

**Table 20 : Estimated direct costs of Respiratory Infections.**

	Respiratory Infection		
	Before electrification	After electrification	Change
<b>Total cost of transport to GP's</b>			
Total nr. of GP contacts	32344144.00	32344144.00	
% Black, Coloured and Asian	37.80	8.90	-76.45%
% due to	21.21	21.21	
Nr. due to	2593152.93	610687.52	-1982465.42
% using public transport	50.00	50.00	
% using private transport	50.00	50.00	
Cost of private transport/km	\$0.27	\$0.27	
Cost of public transport	\$0.80	\$0.80	
Average distance travelled (km)	6.00	6.00	
To GP transportation cost	\$4,190,535.14	\$986,871.03	(\$3,203,664.11)
<b>Total cost of transport to Specialists</b>			
Total nr. of Specialist contacts	16655856	16655856	
% Black, Coloured and Asian	22.6	5.3223	-76.45%
% due to	10.1	10.1	
Nr. due to	380186.57	89533.94	-290652.63
% using public transport	50	50	
% using private transport	50	50	
Cost of private transport/km	\$0.27	\$0.27	
Cost of public transport	\$0.80	\$0.80	
Average distance travelled (km)	6	6	
To Specialists transportation cost	\$614,381.50	\$144,686.84	(\$469,694.65)

**Table 20 : Estimated direct costs of Respiratory Infections (Continued).**

	Respiratory Infection		
	Before electrification	After electrification	Change
<b>Total cost of ambulance transport to hospital</b>			
Total nr. of patients conveyed by Cape Town ambulances	176475.00	172690.42	
Nr. due to	7735.00	3950.42	
As % of total conveyances	4.38	2.29	
% Blacks, Coloureds and Asians transported (*)	64.00	29.51	
Nr. of Blacks, Coloureds and Asians conveyed by Cape Town ambulances due to	4950.4	1165.82	-76.45%
Population of South African provinces	20240416.00	20240416.00	
Population of Cape Town	2102764.00	2102764.00	
Population of Cape Province	6125335.00	6125335.00	
Cape Province ambulance budget	91554000.00	91554000.00	
Total cost of ambulance transport to hospital	\$8,486,410.07	\$2,042,348.60	(\$6,444,061.47)
* : Use % Blacks, Coloureds and Asians discharged for respiratory infections as a proxy.			
	Respiratory Infection		
	Before electrification	After electrification	Change
<b>Total cost of public &amp; private transport to hospital</b>			
Total nr. of Black, Coloured and Asian patients transported by ambulance due to	47650.69	11221.74	-36428.95
Nr. of Black, Coloured and Asian patients discharged from hospitals	253494.00	59697.84	-76.45%
Total nr. of Black, Coloured and Asian patients using public or private transport	205843.31	48476.10	-157367.21
% using public transport	50.00	50.00	
% using private transport	50.00	50.00	
Average distance travelled (km)	20.00	20.00	
Total cost of public transport to hospital	\$164,674.65	\$38,780.88	(\$125,893.77)
Total cost of private transport to hospital	\$1,119,787.61	\$263,709.98	(\$856,077.63)
Total public & private hospitalisation transport cost	\$1,284,462.25	\$302,490.86	(\$981,971.39)

**Table 20 : Estimated direct costs of Respiratory Infections (Continued).**

	Respiratory Infection		
	Before electrification	After electrification	Change
<b>Total GP consultation cost</b>			
Total nr. of Black, Coloured and Asian GP contacts due to	2593152.93	610687.52	-1982465.41
Price of GP consultation (MASA rate)	\$55.20	\$55.20	
Price of GP consultation (S/B rate)	\$24.80	\$24.80	
Total GP consultation cost (MASA rate)	\$143,142,041.74	\$33,709,951.10	(\$109,432,090.63)
Total GP consultation cost (S/B rate)	\$64,310,192.66	\$15,145,050.50	(\$49,165,142.17)
<b>Total Specialist consultation cost</b>			
Total nr. of Black, Coloured and Asian Specialist contacts due to	380186.57	89533.94	-290652.63
Price of Specialist consultation (MASA rate)	\$150.00	\$150.00	
Price of Specialist consultation (S/B rate)	\$100.00	\$100.00	
Total Specialist consultation cost (MASA rate)	\$57,027,985.50	\$13,430,091.00	(\$43,597,894.50)
Total Specialist consultation cost (S/B rate)	\$38,018,657.00	\$8,953,394.00	(\$29,065,263.00)
<b>Total state hospitalisation cost</b>			
Annual budget of state hospitals in SA	\$5,037,696,000.00	\$5,037,696,000.00	
Total nr. of discharges from state hospitals	481873.00	455836.42	
Total nr. of Black, Coloured and Asian discharges due to	34057.00	8020.42	-76.45%
% Black, Coloured and Asian discharges due to	7.07	1.76	
Weighting factor for typical cost of	1.00	1.00	
Total state hospitalisation cost	\$356,045,706.38	\$88,638,058.09	(\$267,407,648.30)
Total direct cost	\$472,950,345.01	\$116,212,899.91	(\$356,737,445.10)

(Sources : Pestana, 1993; Census of hospitals etc., 1990; Zwarenstein, in press; Bourne, 1991 & in press)

Direct cost category	Direct cost of respiratory infections
Change in total cost of transport to GP's	(R3,203,664.00)
Change in total cost of transport to Specialists	(R469,695.00)
Change in total cost of ambulance transport to hospital	(R6,444,061.00)
Change in total cost of public & private transport to hospital.	(R981,971.00)
Change in total GP consultation costs	(R4,916,514.00)
Change in total Specialist consultation costs	(R2,906,526.00)
Change in total state hospitalisation costs	(R2,674,076.00)
<b>Change in total direct costs</b>	<b>(R3,567,374.00)</b>

**Table E** : The change in total direct cost of respiratory infections due to electrification.

## 4.2. Paraffin poisoning and burns.

The economic savings that can be attributed to the health impact of electrification on paraffin poisoning and burns are discussed together mainly because of the way the impact on paraffin poisoning and burns was calculated. The equation used to calculate the impact of electrification on paraffin poisoning relates the number of litres of HH paraffin sold to the number of paraffin poisoning cases hospitalised each year. Similarly, the methodology used to calculate the impact on burns included the use of a fatality-case ratio (FCR). This FCR was calculated from the Cape Metropolitan area study (Abrahams,1994). It was explicitly calculated as a ratio of deaths to hospitalised cases (or at least receiving initial treatment at a hospital). Thus, Tables 18 and 19 report specifically the impact of electrification on the number of hospitalised cases. Furthermore, the data used to calculate the direct cost of hospitalisation reports the number of patients discharged for Accidents, Poisonings and Violence in aggregate (Census of hospitals,1990). This means that

it is impossible to distinguish between burns and paraffin poisoning. Also, no data on the number of these or other cases that may visit a GP exist. There is thus no clear indication of how to link the data of Tables 13 and 14 to anything other than the 'Total cost of state hospitalisation' on Table 17.

Table C summarised the health implications of a reduction in the use of paraffin due to wider access to electricity. It shows the expected improvement in terms of the reduction in the number of paraffin poisonings. Due to a lack of data, the calculation could not be done for any of the rural areas under study. However, a minimum total decrease of 4899 paraffin poisoning cases can be expected. From box 4 it is also clear that if a FCR=65.79 is used (which is the most conservative estimate) then electrification implies a decrease of on average 35065 (the average of the 'Census' and the 'Calculated' methods) in the number of hospitalised burn cases. The impact of these two health 'savings' can now be analyzed in terms of their economic implications.

#### **4.2.1 Total cost of state hospitalisation**

The decrease of 4899 black, coloured and Asian paraffin poisoning cases combined with a decrease of 35065 black, coloured and Asian burn cases results in a total decrease of 39964 in the number of patients expected to be discharged from hospital after electrification. This means that black, coloured and Asian Accidents, Poisonings and Violence cases now only constitute 3.58% of the total state hospitalisation budget. While the total direct cost of paraffin poisoning and burns might have been over-estimated due to the aggregation into Accidents, Poisonings and Violence, the saving due to the impact of electrification won't be. This saving is calculated to be which also constitutes the total saving R 406 893 573.

This concludes the quantification of the health benefits of a national HH electrification programme. These results may be summarised as follows. The total direct cost of respiratory infections, paraffin poisoning and burns together amount to R 472 950 345, R 542 105 693 and R 1 926 839 respectively before electrification. Due to electrification morbidity as a result of respiratory infections decreases by 76.45%. This implies that the total direct cost of respiratory infections decreases to R 116 212 900 after electrification, which implies a total saving of R 356 737 445. Electrification also results in a decrease of 4899 paraffin poisoning cases as well as a decrease of 35065 burn cases. The total direct cost of paraffin poisoning and burns together therefore decreases by R 406 893 573. Electrification therefore implies a total saving of R 763 631 018 on the direct cost of respiratory infections, paraffin poisonings and burns to the South African economy. Table F summarises these results.

**Table 21 : Estimated direct costs of Paraffin Poisoning and Burns.**

	Paraffin Poisoning and Burns		
	Before electrification	After electrification	Change
<b>Total cost of transport to GP's</b>			
Total nr. of GP contacts	32344144	32344144	
% Black, Coloured and Asian	37.8	37.8	
% due to	0.21	0.21	
Nr. due to	25674.78	25674.78	
% using public transport	50	50	
% using private transport	50	50	
Cost of private transport/km	\$0.27	\$0.27	
Cost of public transport	\$0.80	\$0.80	
Average distance travelled (km)	6	6	
To GP transportation cost	\$41,490.45	\$41,490.45	\$0.00
<b>Total cost of transport to Specialists</b>			
Total nr. of Specialist contacts	16655856	16655856	
% Black, Coloured and Asian	22.6	22.6	
% due to	0	0	
Nr. due to	0.00	0	
% using public transport	50	50	
% using private transport	50	50	
Cost of private transport/km	\$0.27	\$0.27	
Cost of public transport	\$0.80	\$0.80	
Average distance travelled (km)	6	6	
To Specialists transportation cost	\$0.00	\$0.00	\$0.00

**Table 21 : Estimated direct costs of Paraffin poisoning and Burns (Continued).**

	Paraffin Poisoning and Burns		
	Before electrification	After electrification	Change
<b>Total cost of ambulance transport to hospital</b>			
Total nr. of patients conveyed by Cape Town ambulances	176475.00	176475.00	
Nr. due to	465.00	465.00	
As % of total conveyances	0.26	0.26	
% Blacks, Coloureds and Asians transported (*)	82.28	82.28	
Nr. of Blacks, Coloureds and Asians conveyed by Cape Town ambulances due to	382.60	382.60	
Population of South African provinces	20240416.00	20240416.00	
Population of Cape Town	2102764.00	2102764.00	
Population of Cape Province	6125335.00	6125335.00	
Cape Province ambulance budget	91554000.00	91554000.00	
<b>Total cost of ambulance transport to hospital</b>	<b>\$655,889.92</b>	<b>\$655,889.92</b>	<b>\$0.00</b>

\* : Use % Blacks, Coloureds and Asians discharged for Accidents, Poisonings and violence as a proxy.

	Paraffin poisoning & Burns		
	Before electrification	After electrification	Change
<b>Total cost of public &amp; private transport to hospital</b>			
Total nr. of Black, Coloured and Asian patients transported by ambulance due to	10149.65	10149.65	
Nr. of Black, Coloured and Asian patients discharged from hospitals (*)	389904.00	389904.00	
Total nr. of Black, Coloured and Asian patients using public or private transport	379754.35	379754.35	
% using public transport	50.00	50.00	
% using private transport	50.00	50.00	
Average distance travelled (km)	20.00	20.00	
Total cost of public transport to hospital	\$303,803.48	\$303,803.48	
Total cost of private transport to hospital	\$2,065,863.68	\$2,065,863.68	
<b>Total public &amp; private hospitalisation transport cost</b>	<b>\$2,369,667.16</b>	<b>\$2,369,667.16</b>	<b>\$0.00</b>

\* : Figure used for paraffin poisoning and burns is nr. of Black, Coloured and Asian patients discharged for Accidents, Poisonings and Violence.

**Table 21 : Estimated direct costs of Paraffin poisoning and Burns (Continued).**

	Paraffin Poisoning and Burns		
	Before electrification	After electrification	Change
<b>Total GP consultation cost</b>			
Total nr. of Black, Coloured and Asian GP contacts due to	25674.78	25674.78	
Price of GP consultation (MASA rate)	\$55.20	\$55.20	
Price of GP consultation (S/B rate)	\$24.80	\$24.80	
Total GP consultation cost (MASA rate)	\$1,417,247.86	\$1,417,247.86	
Total GP consultation cost (S/B rate)	\$636,734.54	\$636,734.54	\$0.00
<b>Total Specialist consultation cost</b>			
Total nr. of Black, Coloured and Asian Specialist contacts due to	0.00	0.00	
Price of Specialist consultation (MASA rate)	\$150.00	\$150.00	
Price of Specialist consultation (S/B rate)	\$100.00	\$100.00	
Total Specialist consultation cost (MASA rate)	\$0.00	\$0.00	
Total Specialist consultation cost (S/B rate)	\$0.00	\$0.00	\$0.00
	Paraffin poisoning & Burns		
	Before electrification	After electrification	Change
<b>Total state hospitalisation cost</b>			
Annual budget of state hospitals in SA	\$5,037,696,000.00	\$5,037,696,000.00	
Total nr. of discharges from state hospitals	481873.00	441908.97	
Total nr. of Black, Coloured and Asian discharges due to	51500.00	11535.97	-4899.28-35064.745
% Black, Coloured and Asian discharges due to	10.69	2.61	
Weighting factor for typical cost of	1.00	1.00	
Total state hospitalisation cost	\$538,401,910.88	\$131,508,337.58	(\$406,893,573.30)
Total direct cost	\$542,105,692.95	\$135,212,119.65	(\$406,893,573.30)

(Sources : Pestana,1993;Census of hospitals etc.,1990;Zwarenstein,in press;Bourne,1991 & in press)

<b>Direct cost category</b>	<b>The change in the total direct cost of respiratory infections, paraffin poisonings and burns due to electrification.</b>
Change in total cost of transport to GP's	(R3,203,664.00)
Change in total cost of transport to Specialists	(R469,695.00)
Change in total cost of ambulance transport to hospital	(R6,444,061.00)
Change in total cost of public & private transport to hospital.	(R981,971.00)
Change in total GP consultation costs	(R4,916,514.00)
Change in total Specialist consultation costs	(R2,906,526.00)
Change in total state hospitalisation costs	(R6,743,012.00)
<b>Change in total direct costs</b>	<b>(R7,636,310.00)</b>

**Table F : The change in total direct cost of respiratory infections, paraffin poisonings and burns due to electrification.**

## Chapter 5

# The Macroeconomic implications of the health benefits of electrification.

At face value, the fact that the saving in the direct costs of treating respiratory infection, paraffin poisoning and burn cases due to electrification amounts to R 763 631 018 means that the electrification project is a good idea. However, some cautionary notes are in order.

One must be very clear about what it is being quantified when calculating this direct cost saving. As will be pointed out in more detail below, the South African economy will not immediately experience a net reduction in demand for health services equalling R 763 631 018. The reason for this is twofold: Firstly, a large part of the R 763 631 018 is government expenditure on health, which will not be taken out of the economy even if there is a reduced demand for health services, primarily due to a current excess demand for health services. Secondly, expenditure in the private sector will have a multiplied effect on the economy. It is therefore essential to analyze exactly what the real impact of the reduced demand for health will be on the South African economy, and not to simply assume that the full amount will impact directly on the economy. It is the aim of this chapter to analyze this problem.

The section below analyses the real impact of a reduced demand for health services on the South African economy. From a macroeconomic perspective the interest lies in the flow of money, not pure demand. It is therefore necessary to analyze the changes in expenditure that will result from the reduced demand for health services. Health services however are produced both in the private and the public sector. The impact of a reduced demand for health services will differ significantly between these two sectors of the economy, and will therefore be discussed separately.

### 5.1. The implications of a reduced demand for health as a public good.

The largest component of aggregate expenditure is consumption expenditure by HH's. This consists both of an autonomous and an induced consumption component and can be expressed as follows:

$$C = C^* + cY \quad \text{where} \quad 0 < c < 1$$

where  $C^*$  denotes autonomous consumption, and  $cY$  induced consumption and where  $c$  denotes the marginal propensity to consume.

Autonomous consumption is generally regarded as a subsistence level of consumption. It can therefore be expected that expenditure on health to be induced by increases in income, i.e. that more is spent on health as income levels rise. However, lower income HH's (<R750/m) are charged a flat rate of R10 for any health service provided by state hospitals, of which, to use the example of Groote Schuur hospital, only 3% of all these bills are ever paid (Personal communication). Hence it must be concluded that the real incomes of the currently non-electrified HH's will only change marginally once they are electrified. Induced consumption expenditure on health will therefore also remain constant. From a macroeconomic point of view, personal consumption expenditure will therefore remain fairly constant. HH welfare however will improve due to the fact that they experience an improvement in health as a result of electrification. Depending on the price of electricity relative to other previously utilised energy sources, this increase in welfare will either be eroded or increased. Rational behavioural assumptions however dictate that HH's will only switch to electricity if their welfare improves by making this switch.

It is therefore concluded that the first component of aggregate expenditure (AE), namely consumption expenditure (C), will remain constant even though HH's demand fewer health services from the public sector.

The second component of aggregate expenditure is investment expenditure (I) by firms. Investment expenditure is expenditure on capital or assets. While it may be expected that there will be a change in the employment of capital in the public health sector due to the changes that will occur in demand, this change will be reflected under government expenditure, the third component of aggregate expenditure, since factors in this sector are employed by means of government funds.

As mentioned above, the third component of aggregate expenditure is expenditure by government (G). Government expenditure is reflected in the annual national budget produced by the ministry of finance. The previous chapter showed that the direct cost of government financed respiratory infection, burn and paraffin poisoning treatment amounts to R 894 447 617 out of a total annual state hospital budget of R 5 037 696 000 in 1991. This is in other words the annual cost of producing health as a public good. What should be added to this is the cost of government financed ambulance transport to hospitals. This amounted to an annual cost of R 10 294 024 for respiratory infections, paraffin poisoning and burns cases.

A reduction in the demand for health services amounting to R 674 301 221 and ambulance transport to hospital of R 6 444 061 due to electrification will not necessarily lead to a reduction in the national health budget. There are two reasons for this. The first is that the benefits of electrification were calculated under the assumption of full electrification. Assuming that this goal will be achieved within a 20 year period (more details of which will be given below), the benefits of electrification will be spread over this period. Hence, the full impact will not be felt immediately. The second is because of government failure. A typical

characteristic of bureaucracies is that departments aim to maximise the size of their budgets, since budget size is directly related to political status. Furthermore, failure to fully utilise the annually allocated budget will mean a smaller budget during the next financial year. For these two reasons one can expect that hospitals which face a reduced demand for certain health services over a 20 year period will not give up the saving on their annual budget, but will more probably reallocate it in the next financial year to areas suffering from insufficient funds.

The net effect of a reduced demand for respiratory infection, burn and paraffin poisoning treatment can therefore be expected to be a budgetary reallocation to other forms of treatment rather than a reduced budget size. What is important to note is that the marginal benefit of government expenditure within the respiratory infection, paraffin poisoning and burns units will decline sharply. At the same time, the reallocation to other units will again increase this marginal benefit. This reallocation should therefore lead to its own improvements in the health status of individuals over time, thus reducing the demand for health services even further and leading to even more budgetary reallocations. In other words, the exogenous input into the health services sector, namely electrification, can be expected to create its own health multiplier effect, leading not necessarily to a reduction in the national budget, but rather to a successive budgetary reallocation and health improving process. Over time budgetary health expenditure should be reviewed, and only the strength of the health lobby will determine whether the saving generated by electrification will stay within the health sector and simply be reallocated, or whether it will be allocated to sectors other than health.

The reduction in demand for certain health services will also impact on the labour and capital markets of the public health sector of the economy. It will test factor mobility in the health sector. If fewer services are required in the respiratory infection, burns and paraffin poisoning departments, labour and capital currently employed there will either have to move to other sections, or be unemployed, or be less overemployed, depending on the current state of the labour and capital markets. It can be expected that both labour and capital will be very mobile due to the unspecialised nature of the disorders we are concerned with. Furthermore, one can expect the reduction in demand simply to alleviate a current excess demand for health services, rather than leading to a complete cessation thereof. Unemployment of labour and capital in the health sector due to a reduced demand for health services is therefore quite unlikely.

The conclusions drawn from this macroeconomic analysis of the implications of a reduced demand for health services provided in the public sector are therefore as follows:

- Consumer expenditure will remain constant.
- Household welfare will improve.

- Government expenditure will be reallocated - in the short term within the health sector itself, in the long run it is uncertain where it will be allocated.
- The reallocation within the health sector will lead to a multiplier effect on the health status of HH's.

The policy implications of these conclusions are:

- Electrification is a good idea due to the fact that it improves household welfare.
- An attempt must be made to monitor the budgets of state institutions affected by the health benefits of electrification, and care must be taken to ensure that the resources freed up by the reduced demand in certain areas of the health sector be reallocated to areas needing attention the most. This reallocation must not only be based on a health justification, but also on an economic one. The meaning of this statement will become clearer when the cost-effectiveness of electrification as a health intervention is evaluated. However, in short, an allocation should be made to the health intervention with the highest opportunity cost, or in other words, that is most cost-effective on a per rand spent basis. However, to be able to make such an informed decision in the first place, more interdisciplinary research, especially of an economic nature, should be done to inform health policy decisions. This type of evaluation will become even more important in the long run due to the multiplied health effect of electrification. Focusing on the cost-effectiveness of government expenditure in this way will ensure an optimal allocation of very limited resources and help maximise the benefits of government intervention as well as minimise government failure.

With reference to the cost-effectiveness study that will still be done, it is clear that despite the lack of a budgetary saving, the reallocation of funds improves the marginal benefit of government expenditure. This is as good as a net increase in government expenditure. However, instead of increasing resources in areas already plagued by severe diminishing returns, resources are rather reallocated from areas with diminishing returns, to areas where the marginal benefit is still quite high. One should therefore include not only the R 680 745 283 immediate saving in the direct costs of treating respiratory infections, paraffin poisoning and burns, but rather some multiple thereof to take into account the multiplied health impact due to the budgetary reallocation process.

## **5.2. The implications of a reduced demand for health as a private good.**

The suppliers of health in the private sector are general practitioners (GP's) and specialists in private practice as well as private or fee-for-service hospitals. Due to the income level of the HH's under

consideration in this study, it is an accurate assumption that a very negligible number of private hospital patients fall within this category due to private hospital's fee-for-service policies and generally higher fees for treatment as well as their location in relation to the newly electrified areas. The reduction in demand for health as provided by these private institutions will therefore be small enough to be ignored at a macroeconomic level.

The total annual cost of GP and Specialist consultations due to black, coloured and Asian respiratory infections, burns and paraffin poisoning cases amounts to R 103 693 281. Electrification will mean that a total of R 78 230 405 less is spent on these privately produced health services. This result has more severe implications than those discussed above because of the real income effects.

The HH's which were forced to spend R 78 230 405 in total due to the utilisation of dirty fuels will experience an increase in real income since they now have the freedom to allocate their consumption expenditure somewhere else. They also experience an improvement in welfare due to an improved health status. However, at the same time, the GP's and Specialists will experience a decrease in income amounting to R 78 230 405 (pre-tax). The reduced demand for health as a private good therefore generates a positive multiplier effect in the form of an increase in induced consumption expenditure by lower income HH's, and a negative multiplier effect due to reduced health expenditure. Whether this will result in a net positive or negative impact on the economy depends on the relative size of the two multiplier effects. The multiplier effect is dependent on the marginal propensities to consume of all the HH's involved in the chain of events generated by the initial exogenous shock to the economic system, which in this case is electrification.

The positive multiplier effect can be decomposed as follows. Firstly, lower income HH's experience a total increase in real income equal to R 78 230 405. Of this they will spend  $(c^l \times R 78 230 405)$ , where  $c^l$  denotes the marginal propensity to consume of the lower income HH's. This expenditure will become the income of other HH's in the economy, which in turn spend  $c^R(1-t) \times (c^l \times R 78 230 405)$  if it is assumed that  $c^R$  denotes the marginal propensity to consume of the rest of the HH's in the economy and that  $t$  denotes an average income tax rate. If this process continues forever within a closed economy, the total positive multiplied effect on the South African economy will be equal to

$$R78230405 + (c^l * R78230405) + \left( \frac{1}{1 - c^R(1-t)} * c^l * R78230405 \right) \quad (14)$$

$$= R78230405 \left( 1 + c^l \left( 1 + \frac{1}{1 - c^R(1-t)} \right) \right) \quad (15)$$

where  $0 < c^1, c^R, t < 1$ .

The negative multiplier effect starts when GP's and Specialists experience a decrease in pre-tax income amounting to R 78 230 405 due to the fact that fewer respiratory infection, burn and paraffin poisoning cases come to them for treatment. Since they would have been taxed on this income at some tax rate  $t$ , as well as having spent a fraction  $c^2$  of it, where  $c^2$  denotes the marginal propensity to consume of higher income earners, only  $(c^2(1-t) \times R 78 230 405)$  will be taken out of the economy. However, this means that someone else who would have earned part of his/her income from the expenditure by these GP's and Specialists, will now experience a decrease in income (cumulatively) of  $c^R \times (c^2(1-t) \times R 78 230 405)$  etc. where  $c^R$  again denotes the marginal propensity to consume of the rest of the HH's in the economy. The total negative multiplied effect on the economy therefore amounts to

$$R78230405 (1-t) + R78230405 (1-t)c^2 + R78230405 (1-t)c^2 \left( \frac{1}{1-c^R(1-t)} \right) \quad (16)$$

$$= R78230405 (1-t) \left( 1 + c^2 \left( 1 + \frac{1}{1-c^R(1-t)} \right) \right) \quad (17)$$

Comparing the positive and the negative multiplier effects it can be seen that it is equal to :

$$R78230405 \left( t + \frac{(c^1 - (1-t)c^2)}{1 - c^R(1-t)} \right) \quad (18)$$

If the assumption is made that  $c^1 > c^2$ , in other words, that the marginal propensity to consume of the lower income groups is higher than that for the higher income group's, then the reduced demand for health services provided in the private sector leads to a net positive multiplier effect.

By taking very crude averages across South Africa, it is possible to get an estimate of the size of this effect. The marginal propensity to consume taken across the whole of the South African population is approximately 0.95. Assume therefore that  $c^1 = c^R = 0.95$ , and that  $c^2 = 0.80$ . The marginal tax rate is a good indicator of the average income tax rate paid by all individuals in South Africa, and is currently 25%. Based on these estimates it can be established that the net positive multiplier effect will amount to  $1.4673 \times R 78 230 405 = R 114 787 470$ . In other words, the initial reduction in demand for health services provided in the private sector which was quantified as R 78 230 405, leads via a multiplier effect to

a net national increase in income levels of R 114 787 470. Table G summarises the impact of the reduced demand for health services on the South African economy.

Public sector	Private sector	Total
R680,745,283.00	R114,787,470.00	R795,532,753.00

**Table G** : Net impact on the South African economy due to electrification.

This is a very powerful result in that it puts into perspective the magnitude of the health impact of electrification. It re-emphasises the role that electrification can play in an overall package aimed at improving the economic status of all South Africans. It also forces one to recognise the relative efficiencies of different forms of government expenditure. It has been established that by promoting electrification, not only does it improve the environment and enrich peoples lives, but it also improves the health status of the newly electrified, to the extent that purely from the private sector an injection of R 114 787 470 into the economy follows due to the real income and welfare improvement of currently non-electrified HH's.

One component of the direct costs calculated before that will have no direct impact on the South African economy, is non-ambulance transportation for health purposes. While those that are currently ill will experience an increase in real income due to the saving generated by the reduced need for expenditure on transportation for health reasons, this will be directly offset by the similar reduction in real incomes of the suppliers of transport. The result will be a slight restructuring of demand in the economy.

This concludes the macroeconomic assessment of the implications of a reduced demand for health services generated by electrification.

## Chapter 6.

### **The impact of the health benefits of electrification on the financing requirements of the national HH electrification programme.**

While the health benefits of electrification as well as the macroeconomic implications have been thoroughly discussed, the cost-effectiveness of electrification as a health intervention has not. To do so involves looking at the electrification project as producing health as well as electricity. From an economic perspective this will mean the inclusion of the quantified health benefits of electrification along with the revenue generated by the selling of electricity in the future stream of income generated by the electrification project. Once this is done it can be compared with the cost structure of the process of electrification to evaluate the cost-effectiveness of the project.

This analysis will be done at two levels. Firstly, the financially oriented approach followed by the National Electrification Economic Study (NEES,1993) will be re-evaluated taking into account the health benefits of electrification. Secondly, an economic theoretical approach will be followed, using microeconomic theory of the firm and consumer behaviour to investigate the determinants of the success of the electrification project, which is discussed in Appendix C.

The National Electrification Economic Study:Phase 1, a part of the National Electrification Forum (NELF), specifies three scenarios for the electrification of South Africa (NEES,1993). These scenarios differ in terms of both the rate of electrification as well as the total percentage of South African HH's that will gain access to electricity by the year 2012. Clearly this also implies different financing requirements for each scenario. Table H gives a short summary of each of the three scenarios.

	Scenario 1	Scenario 2	Scenario 3
% access in 2012	59%	80%	92%
Net Present Value (billions of Rands)	(R10.50)	(R19.40)	(R27.80)

**Table H** : Summary of NEES electrification scenarios (Source : NEES,1993).

As can be seen from Table H all three scenarios result in a negative Net Present Value. In short, this means that the present value of the future stream of capital and operating costs of the electrification project exceed the present value of the future income stream generated by selling electricity. The two main factors causing a negative net present value are firstly the excessive capital costs of especially rural connections, and secondly the lack of electricity utilisation by newly-electrified HH's which results in an average electricity consumption well below Eskom's breakeven consumption level.

It is not the aim of this paper to reevaluate the financing requirements of the electrification project, but rather to add to it by including the quantified health benefits of electrification in the future income stream generated by the electrification project and re-evaluating the financial viability of the project.

By analyzing the macroeconomic implications of the health benefits of electrification, the revenue generated by the second stage of a two-stage production process has been identified. The first stage is the production of electricity using certain factors of production such as land, labour and capital. The revenue and costs involved in this production process have been fully investigated by NEES, the result of which is the net present values shown in Table H. The health benefits of electrification is essentially the output of a second stage production process, where the factor of production is electricity itself and the output is health. Clearly there are no further costs involved in this production process. However, the revenue generated through the production of health was pointed out in the previous section as the macroeconomic implications of the health benefits of electrification. A financial evaluation of the electrification project is incomplete without including the revenue generated in this way by the second stage production process in the future stream of income generated by electrification. It is therefore the aim of this section to do just that, i.e. add the quantified health benefits of electrification to the analysis done by NEES and re-evaluate the financing requirements of the national HH electrification project.

It was shown before that the reduced demand for health as a public good did not imply any changes in consumption expenditure by HH's due to the fact that their real incomes remained constant. Their welfare however did improve due to their improved health status. Due to the nature of the public sector, a process of budgetary reallocation as well as a multiplied health improvement effect was identified. This meant that a effectively a minimum of R 680 745 283 is injected into the public health sector of the economy due to electrification. A further net positive injection into the private sector of R114 787 470 was also identified due to the increase in real incomes experienced by the lower income groups due to the welfare improvement stemming from an improved health status due to electrification.

Both these positive impacts on the South African economy must be attributed to the second stage of the electrification production process. However, this benefit was calculated based on a full electrification assumption. This calculation can now be aligned with each of the three different electrification scenarios

identified by NEES. While some accuracy is lost by only including the specifics of the electrification project at this late stage, very little will be gained in terms of accuracy by including it at every stage of the calculation of the health benefits of electrification.

Table 23 shows the results of the above present value calculation. As can be seen on the Table, the present value of the health benefits of the electrification program under scenario 1 with a final total access to electricity of 59% is R 343 613 568. Under scenario 2, with a final total number of HH's access figure of 80%, the present value is R 447 863 310. Under scenario 3, with an access figure of 92%, the present value is R 515 959 583.

Table I shows the impact on the financing requirements of the national HH electrification programme when including the results of this present value calculation in the net present values shown in Table H.

The conclusion to be drawn is that despite the addition of the revenue generated by the second stage of the electrification production process, the net present value remains significantly negative, and hence its viability remains in question. While it was hoped that the magnitude of the health benefits of electrification would be of such a nature as to make the electrification project economically viable, this is clearly not the case. The percentage increase in net present value ranges from 3.27% in scenario 1 to 1.86% in scenario 3. The only conclusion left to draw is that the health benefits of electrification can neither be used as a tool for lobbyists of the electrification project, nor as a source of cross-subsidisation for the electrification project if argued from an economic perspective. While this is a somewhat disheartening result measured in rands and cents, the fact remains that the paper has established if nothing else an ethical case for the electrification project. The vast improvement in the health status of lower income groups that results from gaining access to electricity, again points out the harms of the apartheid system, as well as the huge gains that can be made simply by establishing equity in access to basic resources.

The conclusions drawn from these results must not only be seen from a macroeconomic perspective, but also from the microeconomic level underlying and determining the actual outcome of the electrification programme. Appendix C highlights certain key determinants of the already mentioned outcome in an attempt to inform public policy not only by outlining its symptoms, but also by analyzing its causes.

	<b>Scenario 1</b>	<b>Scenario 2</b>	<b>Scenario 3</b>
<b>% access in 2012</b>	59%	80%	92%
<b>Net Present Value (billions of Rands)</b>	(R10.50)	(R19.40)	(R27.80)
<b>Present Value of the health benefits of electrification</b>	R343,613,568.00	R447,863,310.00	R515,959,583.00
<b>Net Present Value with health benefits included (billions of Rands)</b>	(R10.16)	(R18.95)	(R27.28)
<b>% reduction</b>	3.27%	2.31%	1.86%

**Table I : Including the health benefits of electrification in the Net Present Value of the electrification programme.**

## Conclusion

This thesis attempted to investigate the health benefits of a national HH electrification programme. It did this taking cognisance of the fact that electricity provision does not necessarily lead to electricity use by using the behaviour of previously electrified HH's as a model for the expected behaviour of currently non-electrified HH's once they gain access to electricity.

The most significant health benefits of electrification were a 76.45% reduction in respiratory infection morbidity due to a decrease in air pollution levels, 4899 fewer paraffin poisoning cases and 35065 fewer burn cases.

These health benefits were shown at a macroeconomic level to result in a R 795 532 753 net injection into the South African economy due to its impact on both the public and private health services sectors. Placed within the scope of the proposed national HH electrification programme this translates into a present value of between R 343 mil. and R 515 mil. depending on the extent of electrification over the next 18 years.

As was pointed out in the introduction, this clearly establishes a strong ethical case for the electrification programme by showing the impact of equity in access to electricity. However, at a cost of between R 10.5 bil. and R 27.8 bil. the financial viability of electrification as a health intervention is highly suspect.

This result can however not be seen in isolation. Firstly, it was shown that there are several factors inhibiting the success of the electrification programme, amongst which is the lack of a secondary market for coal stoves and a lack of education about the benefits of electricity. Secondly, this thesis only quantified the health benefits of electrification. As was pointed out, the entire socio-economic environment is affected, and these must also be considered to complete the electrification picture. Lastly, the health impact of electrification will be complimented by a similar expansion in access to water, sanitation and educational facilities.

## Limitations

A criticism of the methodology used to establish the extent to which newly electrified HH's will switch to electricity for all their HH energy needs is that the electrified groups are themselves continually changing. However, if one takes into account the number of years they have been electrified, one may be able to establish where currently non-electrified HH's will be within that period of time, ie. establish the rate of substitution over time and adjust predictions accordingly. In other words, the prediction being made namely the percentage of currently non-electrified HH's that will switch to electricity for all purposes, is made for that point in the future when they will have been electrified for a similar period to which the current electrified group has been electrified. Longitudinal studies are being done in Cape Town on newly-electrified HH's to establish the rate of switching to electricity per year. This will enable one to make predictions for any period in the future, assuming these rates remain constant both over time and across different sectors of the country.

One may also be able to enhance this methodology by making some qualitative statements about the inherent substitutability of electricity for current fuels, such as the space-heating ability of coalstoves. However, the chosen methodology can be likened to revealed preference theory, where most of these characteristics will be revealed in the consumer's choices. This emphasises the non-homogeneity of the HH's under study as is revealed by the variety of their choices as far as energy-use is concerned. The need for a scenario based macroeconomic approach is therefore rejustified to take account of this.

The prediction about the extent of the switch to electricity is made at a very aggregated level, ie. comparing purely non-electrified to electrified groups. More accurate results may be achieved by working at a more disaggregated level. However, data will simply become more sparse, and the ability to make cross-sectorial assumptions will be eroded, thus denuding the lack of data even more.

Some general comments are warranted to clarify the focus of this study. Firstly, due to significant data problems, this study's most optimistic goal is an approximation of the economic implications of electrification via health. While this might be unsatisfactory for the purists, one must recognise that public policy should ideally be informed by proper research. Thus, any attempt to maximise the benefits of public policy should be welcomed.

Secondly, while this study proclaims to quantify all the health benefits of electrification, this is clearly an impossible task. Instead, this study focuses on quantifying the direct rather than the indirect health implications of electrification. The indirect benefits are more difficult to enumerate due to their very nature. Here we are referring to factors such as quality of life, increased life expectancy and population growth. Due to the difficulties with quantification of these benefits, they will not be discussed any further. This

means that several factors which might be regarded as very significant are not analyzed. However, time, space and data constraints prohibit such a thorough study.

Lastly, the focus is on health implications. Electrification will have several direct economic implications. This in itself can also be translated into a health benefit if such an economic saving were to be used to finance health sector activities. This is clearly not in the ambit of this study. The chain of causality being analyzed here is strictly electrification, health, economics and not electrification, economics, health. This immediately disqualifies for instance energy expenditure data and the economic implications of the impact of electrification on the equitable distribution of real income from this study as well as other more economically related matters.

# Appendix A

## An extended modelling methodology

A methodology to establish the extent to which newly electrified HH's can be expected to switch to electricity for all their HH energy needs was outlined in chapter 1. It essentially involved a modelling exercise, where the behaviour of previously electrified HH's in similar socio-economic environments were used as a proxy for the behaviour of newly electrified HH's. At the end of the modelling exercise the fraction of newly electrified HH's expected to switch to electricity was denoted by the letter S, where  $0 < S < 1$ .

S can now be used as a parameter to a second, more refined methodology, where the comparability of the two groups of HH's being used in the model can be analyzed and optimized. S can be adapted depending on the disparity between the socio-economic environmental profiles of the electrified(E) and non-electrified(NE) HH's, which should be reflected in disparate behaviour between the two groups, resulting in different degrees of electricity use. This functional dependence of S on the socio-economic environmental difference between NE and E may be expressed as follows:

$$dS = f ( d(NE,E) )$$

where dS denotes the change in S that will be made dependent on the difference between the environmental profiles of NE and E based on the functional relationship f.

A cross-sectional study should reveal the socio-economic factors that have determined the distribution of electricity use among the currently electrified group. Based on this it should be possible to establish how differences in these factors will lead to different electricity-use distributions. In other words, it should yield enough information to define the functional relationship f mentioned above. Such a study is currently being undertaken by Eskom, but is expected to be completed only at the end of 1994. Some of the most important determining variables of electricity use have been identified. These range from income levels, to access to water and sanitation, to the nature and number of rooms of the dwelling. The specific functional dependencies are still being established. This appendix merely attempts to provide the framework in which added knowledge of electricity use can be accommodated.

To make this clearer, let's look at one possible determinant of the current electricity-use distribution amongst the electrified group, namely mean income. Assume that amongst the non-electrified group three distinct sub-groups based on their mean incomes per month is found. Three different scenarios can then be constructed, each one with a corresponding S reflecting the different degrees to which each of these groups

are expected to switch to total electricity use. As discussed before, the manner in which these income disparities will feature in the functional relationship  $f$  defined above should become clear from a cross-sectional study. Mean income is in other words being used as a proxy for electricity use.

At the end of this part of the methodology one should have established an  $S_1, S_2, S_3, \dots, S_n$  each reflecting different possible switching patterns due to socio-economic differences. A distribution of the non-electrified HH's may then be fitted to these scenarios, resulting in an indication of the overall expected switch to electricity as a sole energy-carrier by the currently non-electrified group once broad access to electricity is provided. Further refinement may result from altering the distribution of non-electrified HH's.

In mathematical terms, this may be restated as follows:

$$dS_1 = f(d(NE_1, E)) \quad \implies \quad S_1 = S + dS_1$$

$$dS_2 = f(d(NE_2, E)) \quad \implies \quad S_2 = S + dS_2$$

$$\begin{array}{l} \cdot \quad \cdot \quad \cdot \\ \cdot \quad \cdot \quad \cdot \\ dS_n = f(d(NE_n, E)) \quad \implies \quad S_n = S + dS_n \end{array}$$

subject to

$$\frac{NE_1 + NE_2 + \dots + NE_n}{T} = 1$$

where  $T$  denotes the total number of HH's and each  $S$  reflects a different scenario based on socio-economic differences between the electrified and non-electrified groups.

The total number of non-electrified HH's expected to switch to total electricity use may then be expressed as:

$$d(NE) = \sum_{i=1}^n S_i \cdot NE_i \tag{19}$$

These scenarios may then be used as a foundation for the subsequent scenario specific environmental impact of electrification study.

## **Appendix B**

### **An evaluation of studies investigating the link between air pollution and health.**

A number of epidemiological studies have been done to establish the link between air pollution and health. They are by no means conclusive. For the most part, these studies take the form of either cross-sectional or case-control analyses. The studies done in the South African context fall into one of two main categories.

Firstly, a number of studies have focused on the health effects of ambient air pollution. These have been primarily case-control studies. They have compared the health condition of individuals in what is known to be areas of high ambient air pollution levels, such as towns in the Vaal Triangle, to individuals living in areas with relatively low ambient air pollution levels. Two studies of most note under this category are Coetzee et al (1986) and Zwi et al (1990) (See Table 15).

The first of these studied the prevalence of RI's in Sasolburg in the Vaal Triangle (the exposed group) vs Parys, Heilbron and Frankfort (PHF) (the control group). Neither the questionnaire survey nor the personal examinations revealed any statistically significant differences between the two groups as far as health is concerned, except for one test, namely the forced expiratory volume in one second performed on the group of boys. A general trend in favour of the PHF was spotted, but was not statistically significant.

The latter of the two studies found similar results when studying exposed vs unexposed white pupils from the eastern Transvaal Highveld. While their questionnaire survey showed respiratory symptoms to be slightly higher among the exposed group, this was not confirmed by personal examinations. No significant differences were found when performing lung function tests either.

The groups studied in the papers mentioned above have several characteristics in common. Firstly, they do not suffer from severe household pollution levels since most of these households were electrified. Furthermore, the type of pollutants experienced here differ from those experienced in areas where the main cause of ambient air pollution are not chemical plants and automobiles, but the domestic use of fuels for cooking and other household requirements. Hence, the applicability of these studies to poor urban and rural households is a priori questionable.

The second category of epidemiological studies have been of a cross-sectional variety. They have taken cross-sections of the South African population and attempted to establish the causal connection between air pollution and health. Results among this category are as contradictory as the above category is inconclusive.

Probably the most influential of these is the Vaal Triangle Air Pollution Health Study (VAPS) (Terblanche et al,1992). It has a very significant list of objectives, not all of which have been achieved yet. Amongst these however, was an attempt to establish a link between domestic fuel exposure on the one hand and URI's and LRI's on the other. Sulphur dioxide(SO<sub>2</sub>) and carbon monoxide(CO) levels were found to exceed international health standards by between 2 and 10 times during peak emission periods. TSP 12 hour exposures also exceeded health standards on average for both rural wood-burning and urban coal-burning households. Based on this type of analysis it was found that urban coal-burning households in non-electrified areas experience 2.9 times higher risks of developing LRI's than households in electrified areas. Whether the control group in this study refers to electrified areas in townships or white electrified areas is not clear, but of great importance. Comparing coal-burning non-electrified township households to white electrified households might serve a political purpose in that it clearly shows the harms of a racially based infrastructure. However, when it comes to studying the true effects of electrification, this comparison is in fact irrelevant. As was seen in the previous chapter, electrification does not imply substitution. The fact that electrified households continue using other fuels imply that ambient air pollution levels will remain relatively high (that is relative to white electrified areas). Hence the conclusion drawn by van Horen of the EDRC (EDRC,1993) :

"The implication is that only full electrification, or put differently, the complete substitution of bituminous coal by cleaner energy sources, occurring on a wide scale in urban areas, will have the effect of reducing people's particulate exposures to acceptable levels(p.19)".

The proper electrified group to compare against in this case would therefore be the electrified township households who still suffer from the high ambient air pollution levels. This was done with a sub-sample of the VAPS study in Sebokeng. The impact of this reasoning shows up quite clearly in the fact that only in a very specific study was a statistically significant difference found between the exposure levels experienced by the non-electrified and the electrified households. It is difficult to predict to what levels the risk assessment of the above mentioned VAPS study will fall based on this criticism. However, if nothing else, it forces one to approach the results of the VAPS study very critically.

Returning to the results of the VAPS study, rural households who were exposed to coal and/or wood fires were found to experience 4 and 5 times higher risks of contracting URI's and LRI's respectively to those not exposed. Even more significant results were found when analyzing the effect of the location of the cooking-fire in the exposed group. The same problem as mentioned above arises with this study in that the non-exposed group is again not clearly defined. It is by no means obvious which comparable rural group will not be exposed to wood and/or coal fires. The VAPS study paper proposes to clearly identify the harmful effects of air pollution. Hopefully the reader will not accept this at face value.

Another cross-sectional paper is that by Kossove (1982). The sample here was 150 Zulu children less than 13 months old from a Zulu outpatient clinic. 88% of the incoming infant patients were diagnosed as falling in a 'wheezing, bronchitis or pneumonia (WBP)' group, and only 12% had no respiratory problems. 70% of the WBP group suffered smoke exposure other than cigarette smoke for 6-7 hours per day, whereas only 33% of the non-respiratory problems group suffered smoke exposure. This difference was statistically significant.

The main problem with this study is the non-randomness of the sample and the complete lack of a control group. The significance of this problem becomes clear if it is imagined that there might be an asbestos mine upwind from this settlement. Clearly these results must be treated with a lot of circumspection and can hardly be used as proof of the harmful effects of air pollution in general.

The last study evaluated here is that done by Ellegard & Egneus (1993). This study was done in Lusaka among housewives cooking with coal, wood and electricity. Exposure and health differences amongst the three groups were analyzed. It became clear that exposure levels differ quite significantly, with TSP exposure being the highest among wood users, then coal users and least among electricity users. CO exposure was highest among coal users, less among wood users and again least among electricity users. Utilising both questionnaire surveys and peak expiratory flow rate (PEF) monitoring it was clear that no statistically significant differences in health status existed between the three different groups.

These studies paint a very complicated picture. The Lusaka study is of particular concern, as it seems to indicate that the HH fuel being used has no impact on respiratory infections. The same concern can be expressed over the fact that ambient air pollution on its own as tested in the Coetzee study mentioned above (Coetzee et al, 1986) also has no significant health effects. Despite this, cases such as the 1950's London air pollution disaster resulted in significant increases in mortality rates. It therefore seems to be the case that under normal circumstances neither ambient nor domestic air pollution levels on their own are high enough to have any significant health impacts. However, it is when they are combined at high enough levels that the health effects become clear. The human system seems to be able to deal with a certain level of air pollution, but the weaknesses in some individuals start showing once a certain critical air pollution level is crossed - which in the South African case requires both high HH and ambient air pollution levels. To show that electrification will have any significant health benefits in South Africa, it is therefore important to show that both HH and ambient air pollution levels will fall significantly enough to induce fewer RI's.

What can be concluded based on this analysis of the available literature on the health effects of air pollution in South Africa and abroad? The South African studies suffer severely from methodological problems. Not only are most of them cross-sectional, which clearly does not establish causality when applied to a non-random sample, but they are also inconclusive. This probably stems from the fact that they measure

exposure levels of variables to which mortality and morbidity are functionally independent (see chapter 1). No other option remains but to ignore the South African studies since no proper conclusions can be drawn from them, and instead to rely on international studies and a priori reasoning.

**Table 15 : Summary of results of basic research papers on the health effects of air pollution.**

Author	Year	Area	Sample	Test	Results
Terblanche et al (A)	1991/2	Vaal Triangle Air Pollution Health Study (VAPS)	Questionnaires: 10187 White 8-12 yrs old Personal monitors: 124 White 8-12 yrs old	Average 12 hr exposure to TSP's URI and LRI	83% > USA AQS(260) > WHO AQS(180)  65% URI past year 28.9% LRI past year LRI: Since birth vs 5yrs significant
Terblanche et al (B)	1991/2	Sebokeng(VT) Urban, Coal-burning Sample of VAPS  Marble Hall Rural wood-burning	45 Black children 8-12 yrs old  34 Farming households	Average 12 hr exposure to TSP's  TSP's SO <sub>2</sub> ,NO <sub>2</sub> ,CO	99% > USA AQS(260) > WHO AQS(180) 662(SD) vs 1333(WD) 1383(NE) vs 1168(E) (WD) - Non-significant 620(NE) vs 387(E) (SD) - Significant  TSP,SO <sub>2</sub> ,CO > USA AQS > WHO AQS
Coetzee,AM Smith,FCA Van der Merwe,CA Dreyer,RJ	1988	Sasolburg vs Parys, Heilbron, Frankfort (PHF)	Questionnaires and Personal examinations of 482 Std.3 Pupils	Ri's	No significant differences between Sasolburg and PHF. Only significant result:Boys' FEV1. General trend (not significant) in favour of PHF.
Zwi,S. et al	1990	Eastern Transvaal Highveld	Questionnaires and Personal examinations of 1031 exposed vs 978 unexposed white std.2&3 pupils	Ri's	Respiratory symptoms very slightly higher among exposed according to QS, not confirmed by tests. Lung function no significant differences.
Kossove,D.	1982	Zulu outpatient clinic	150 Zulu children < 13mths	LRI's	88% WBP vs 12% NRP 70% WBP vs 33% NRP smoke exposure other than cigarette, 6-7 hrs/day. Possible link with TB.
Von Schimming,YER. Yach,D Klein,M.	1991	National	0-14yrs, White,Coloured, Asian and Black	Pneumonia and other ARI's	Average Annual Deaths from Pneumonia: 75% Black from Other ARI's: 68% Black Estimated 13000 infants hospitalised per annum for pneumonia.
Ellegard,A. Egneus,H.	1993	Lusaka	Housewives cooking with: 101 Coal, 94 Wood, 73 Elec.	Exposure and Health using QS and PEF monitoring.	Exposure: TSP's : Wood > Coal > Elec. CO : Coal > Wood > Elec. Health: No statistically significant differences

**Abbreviations:**

VAPS : Vaal Triangle Air Pollution Health Study  
TSP : Total Suspended Particulates  
URI : Upper Respiratory Infections  
LRI : Lower Respiratory Infections  
ARI : Acute Respiratory Infections  
USA AQS : United States Ambient Air Quality Standard  
WHO AQS : World Health Organisation Ambient Air Quality Standard  
E : Electrified Household  
NE : Non-electrified Household  
SD : Summer Day  
WD : Winter Day  
VT : Vaal Triangle  
PHF : Parys,Heilbron,Frankfort  
FEV1 : Forced Expiratory Volume in 1 second  
QS : Questionnaire Survey  
WBP : Wheezing,Bronchitis or Pneumonia  
NRP : Non-respiratory problem  
TB : Tuberculosis

## **Appendix C**

### **A microeconomic approach to the electrification and health problem.**

The entire outcome of the national HH electrification programme depends on the actions taken and decisions made by individual HH's faced with new options in their lives. Microeconomics is a study about the economic behaviour of individuals. It attempts to clarify the decision processes that individuals go through when undertaking any economic activity, such as deciding whether to substitute electricity for coal or not. It should therefore be quite clear that time spent on the microeconomics of the electrification programme is time spent well. If the microeconomic processes underlying the electrification project are understood, they can be manipulated in such a way that the project might become more viable.

The structure of the analysis in this section will be as follows. Firstly, the theory of the firm will be used to analyze the two-stage nature of the production process of the electrification project. This will hopefully highlight the framework in which the electrification project should be thought of, and in which decisions should be made. Secondly, the theory of consumer behaviour will be used to analyze the revenue generated by the electrification project, both from electricity sales and the quantified health benefits of electrification. This will be used to highlight the factors determining the extent of the switch to electricity as well as the resulting health benefits.

#### **The supply-side of the electrification and health project.**

By analyzing the health benefits of electrification, the second stage of a two stage production function is in fact being analyzed. The first stage is the production of electricity using standard factors of production, namely capital, labour, land and entrepreneurship. In the short run, and focusing only on capital and labour where the level of capital is fixed, this can be represented with a typical short-run production. In the long-run capital becomes flexible and isoquant-type analyses is needed to represent the production process. This is the typical first stage production process of the electrification project. However, as has been pointed out, the production of electrification, if utilised, leads to an improvement in health. In other words, a second stage production process exists, where the factor of production is electricity and the output is health. Analyzing the characteristics of this second-stage production function will allow conclusions to be drawn about the production of health in the same way as could be drawn from any normal first-stage production function. This includes looking at the marginal product of electricity in terms of health, the marginal product of labour, land and capital in terms of health, etc. in an attempt to optimise the efficiency of the health production process. This section will merely try and highlight some of these issues.

The shape of the production function is dependent on the marginal product of the factor of production employed. In this case the marginal product of electricity may be defined as the amount by which health improves (which implies that health must be measured in some unit such as the number of cases of ill health avoided) for an increase in electricity production of one unit, or mathematically:

$$MPE = \frac{d(\text{Health})}{d(\text{Electricity})}$$

where MPE denotes the marginal product of electricity.

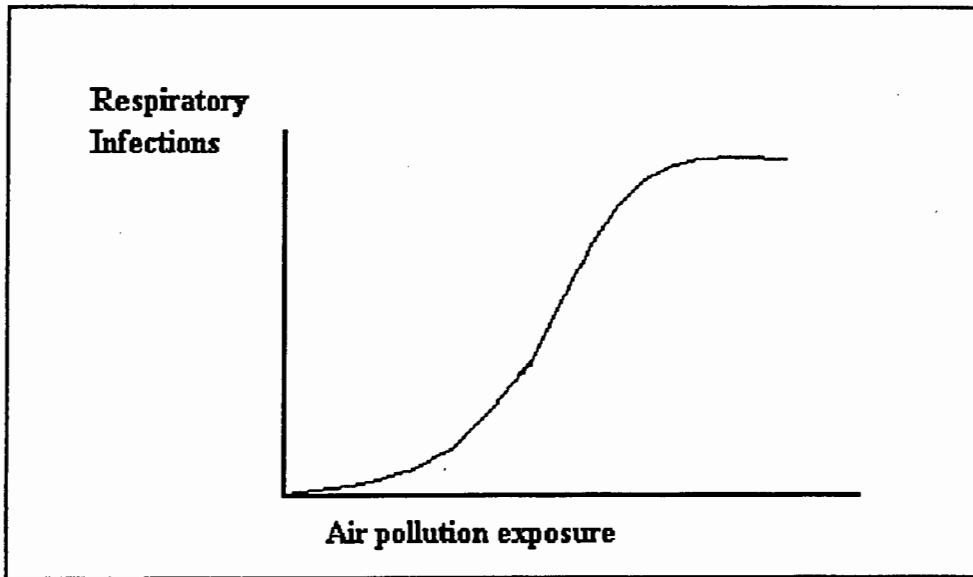
It was established that the health improvement from electrification stems from three main areas, namely reduced respiratory infections due to reduced air pollution, reduced paraffin poisoning cases and reduced burns cases. Based on this the above equation can be expanded as follows:

$$\frac{d(\text{Health})}{d(\text{Elec.})} = \frac{d(\text{Resp.infections}) + d(\text{Paraffin poisoning}) + d(\text{Burns})}{d(\text{Elec.})}$$

This enables a separate analysis of the MPE into an analysis of the MP of electricity in the production of health through avoiding cases of respiratory infections, paraffin poisoning and burns respectively.

The impact that electrification has on respiratory infections is dependent on the impact of electrification on air pollution. In the previous sections it was pointed out that morbidity due to respiratory infections increases in direct proportion to the increases in ambient or HH air pollution levels. It was also pointed out that ambient air pollution is a function of several pollutants, of which the dominant ones are HH air pollution itself, vehicle as well as industrial air pollution. It can be expected that the relationship between air pollution and respiratory infection will not remain a linear one at all levels of air pollution. The linear relationship specified by Ozkaynak(1993) will only hold within a specific range of air pollution levels. Firstly, below some critical level, incidence of respiratory infections will be minimal, and hence the marginal reduction in respiratory infection morbidity due to decreased levels of air pollution will diminish. Similarly, for very high levels of air pollution one can expect the marginal increase in respiratory infections due to an increase in air pollution levels to diminish. Two critical air pollution levels will therefore be where the impact of air pollution on health starts increasing significantly, and where it starts decreasing again due to very high levels of air pollution. Somewhere in between one also has to identify the point of inflection. This seems to indicate that the air pollution health production function, relating air pollution levels to health, has a positive slope that first increases at an increasing rate, then reaches a point of

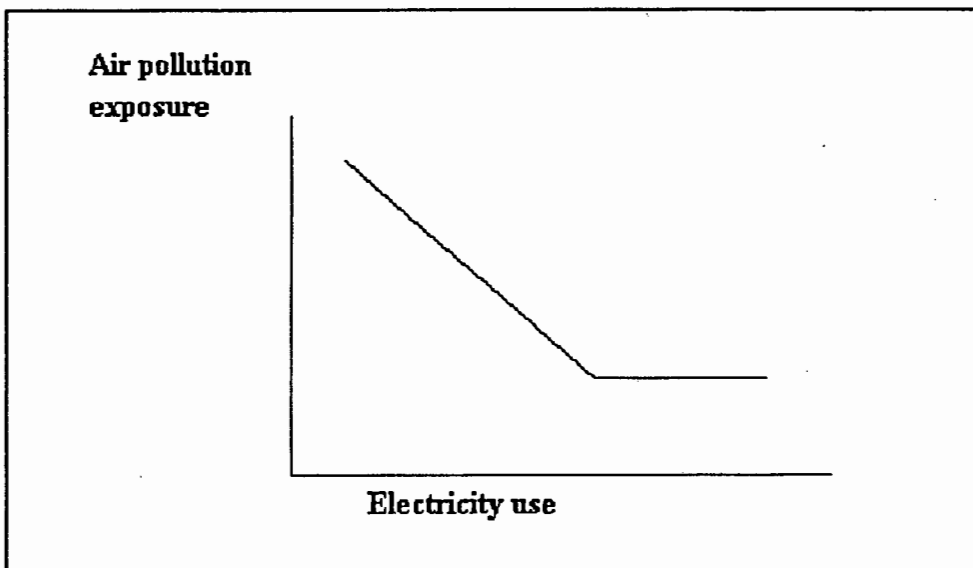
inflection where its slope starts decreasing at an increasing rate, or diagrammatically:



**Figure 1 :** Air pollution health production function.

The impact of electricity provision on air pollution levels can be analyzed as follows. Firstly, ambient air pollution levels, as was pointed out above, are not only a function of HH air pollution levels. Electricity's major impact on air pollution is via its impact on HH air pollution production as was shown above as well (ignoring power station pollution). This implies that the effectiveness of electricity on air pollution levels is partly determined by the extent of the contribution of HH air pollution to ambient air pollution. This will mean that there is a lower level of ambient air pollution which electricity cannot affect. It was assumed before that a reduction in air pollution production will mean a reduction in air pollution exposure levels. This implies that there is a linear relationship between an increase in electricity use and air pollution exposure levels. Diagrammatically this looks as follows:

**Figure 2 :** The relationship between electricity use and air pollution exposure levels.



This analysis allows a specification of the marginal product of electricity in terms of its impact on respiratory infections as follows:

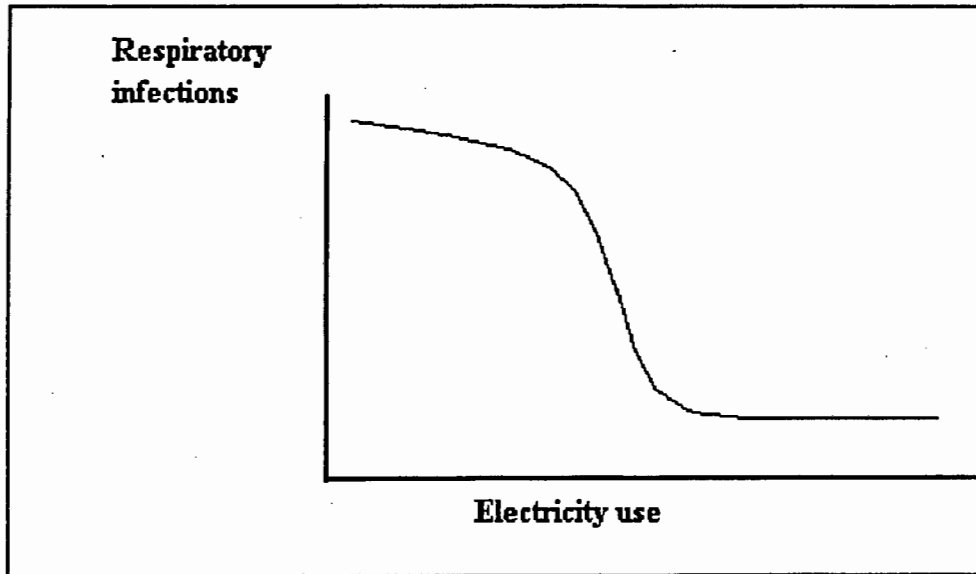


Figure 3 : Marginal product of electricity ito respiratory infections.

Exactly the same reasoning can be applied to the impact of electricity on paraffin poisoning cases and burns. The second stage production function, ie. the production of health through increased electricity provision will therefore look as follows:

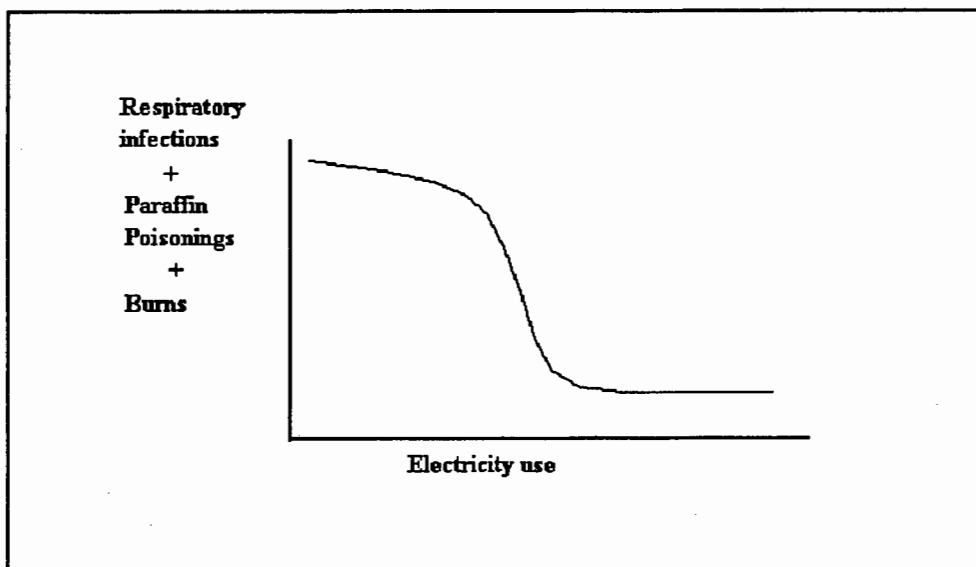


Figure 4 : Marginal product of electricity ito health.

(Note that the horizontal axis is labelled 'Electricity use'. The constraints on electricity utilisation will be highlighted when consumer behaviour is discussed.)

This analysis can now be used as an input into the normal economic analysis that firms do when deciding on production levels. When optimising the production process of any firm, the goal is generally specified as profit maximisation. Looking at health production from an economic/efficiency point of view, this should also be the criteria when analyzing the health production process. Due to the similarity in goals, the second stage production function can now be included in the profit maximisation analyses of the electrification project.

Firms maximise profit where their marginal revenue from producing one more unit of output is exactly equal to the marginal costs (MC) incurred in doing so. Including the second stage production function alters this rule in that the marginal revenue now stems from two sources - electricity sales revenue and direct health cost savings. The marginal revenue from these two sources can be denoted by MRE and MRH respectively. No further costs are incurred in the second stage production function, however, the MC function will change shape due to the fact that the production of health must be added to the productivity analysis of the factors of production producing electricity. This altered MC function is denoted by MCA. Eskom will therefore maximise revenue where  $MCA = MRE + MRH$ .

At this abstract level the applicability of this conclusion might seem rather confusing. However, this is a generic description of a two-stage production process. It provides a framework in which the economic viability of any other project such as housing can also be analyzed. It also helps maximise the efficiency of the resources at our disposal.

## **The demand-side of the electrification and health project.**

The low current levels of HH electricity consumption acts as a major constraint both for the viability of the electrification project, and for its subsequent health benefits. If HH's don't use electricity, Eskom doesn't sell electricity and the potential health benefits of electricity consumption remain untapped. Some of the important factors determining the behaviour of electricity consumers will be highlighted in this section.

With the introduction of electricity, HH's are immediately faced with the option of switching to electricity for their HH energy needs, or not. What determines the outcome of their decision? Economics focuses on the economic factors determining this outcome, such as relative prices of substitutes, prices of complimentary goods and income levels. This study in no way will attempt to fully investigate these factors. However, their role in the decision process mentioned above will be highlighted.

The most important factor determining whether a HH will switch to electricity or not, from an economic perspective, is whether electricity is cheaper than alternative or substitute fuels or not. However, in the case of electricity there is no easy answer to this problem. Firstly, electricity by itself is useless to the HH. The price of complimentary goods, specifically electrical appliances is therefore crucial when investigating the relative price differences between alternative fuels. Secondly, Eckert et al(1993) found significant variability in fuel prices from region to region. This led them to conclude that no specific answer can be given to whether electricity is relatively cheaper or more expensive in general than other fuels. This also means that the impact on HH real incomes is undeterminable in general.

This impact is however very important, since it influences significantly the size of the multiplier effects discussed before in the macroeconomic implications of electrification. This is where the link between micro and macro effects becomes clear. Very slight price differences from region to region will impact on the extent to which electricity is used, the effect on HH real incomes, and finally at a macroeconomic level, the structural adjustments that the entire economy will undergo, not only due to altered energy consumption, but also due to the forward and backward linkages into the labour and capital markets on the one hand, and the appliance and other consumer goods on the other is of great importance when looking at the impact of electrification. The impact of this type of structural shift was shown in this paper through the resulting health benefits. Clearly this is only one of many affected areas of a large scale consumer shift.

Two alternative fuels to electricity dominate in urban South Africa, namely coal and paraffin. What also seems clear is that a far greater percentage of HH's in the predominantly paraffin using areas switch to electricity as sole energy-carrier compared to coal-using areas. Paraffin appliances in common use are primus-type or wick-type paraffin stoves. These appliances represent a far smaller capital outlay than do coal stoves. Thus, when paraffin using HH's are electrified, they do not face such a significant capital constraint as do coal users who's capital is already tied up in a coal stove for which a very limited secondary market exists. Secondly, electricity seems to compete better with paraffin than coal on a cost per unit energy delivered basis. This indicates that thought might be given to establishing an active secondary market for coal stoves to enhance the penetrability of electrical appliances and in doing so increase electricity sales as well as the health benefits that results from this.

This concludes a very brief but important discussion on the microeconomics determining and underlying the outcome of the electrification programme.

## References

- Abrahams N. 1994. Data on burn injuries. National Trauma Research Programme. Medical Research Council of South Africa.
- African National Congress. 1994. A national health plan for South Africa.
- Barnes DF, Openshaw K, Smith KR, van der Plas R. 1993. The design and diffusion of improved cooking stoves. The World Bank Research Observer. Vol.8, No.2, pp.119-142.
- Bourne DE. In press. The morbidity spectrum of specialist physicians in private practice in South Africa. South African Medical Journal.
- Bourne DE, Bloom B, Sayed AR. 1991. The morbidity spectrum seen by general practitioners in South Africa. South African Medical Journal. Vol.80, pp.513-514.
- Bradshaw D, Dorrington RE, Sitas F. 1992. The level of mortality in South Africa in 1985 - what does it tell us about health ? South African Medical Journal. Vol.82, pp.237-240.
- Cargill J. 1993. Reconstruction costs. Finance week. September 23-29. pp.11-12.
- Central Statistical Services. 1987. Census of Hospitals, Clinics, and other health service establishments. Report No. 93-01-01(1987).
- Central Statistical Services. 1990. Census of Hospitals, Clinics, and other health establishments. Report No. 93-01-01(1990).
- Coetzee AM, Smith FCA, van der Merwe CA, Dreyer RJ. 1986. Die invloed van lugbesoedeling op gesondheid in die Sasolburg-gebied. South African Medical Journal. Vol.70, pp.339-343.
- Central statistical services. 1991. Population census.
- Central statistical services. 1990. Report on age specific deaths, stratified according to race.
- Dean DF. 1989. The use of Input-Output modelling to determine the effect of electrification of black urban townships on the South African economy. Eskom.

- de Wet B, Davies MRQ, Cywes S. 1977. Die oorsake van brandwonde by kinders. South African Medical Journal. Vol.52, pp.969-972.
- Dockery DW et al. 1993. An association between air pollution and mortality in six U.S cities. The New England Journal of Medicine. Vol.329, No.24, pp.1753-1759.
- Eckert JB, Greyling A, van Seventer DE. 1993. The Macro-Economics of electrification : A review and extension of existing South African research. National Economics of Electrification Study.
- Edey, Rogers & Co. inc. 1993. Electrification and the consumer appliance market.
- Editorial. 1994. Reel violence. The Lancet. Vol.434, No.8890, pp.127-128.
- Ellegard A & Egneus H. 1993. Urban energy - exposure to biomass fuel pollution in Lusaka. Energy policy. Vol.21, No.5, pp.615-622.
- Ellegard A & Egneus H. 1992. Health effects of charcoal and woodfuel use in low-income households in Lusaka, Zambia. Energy, Environment and Development Series No.14. Stockholm environment institute.
- Epidemiological comments.1993. Vol.20, No.2.
- Eskom. 1994. Electricity Prices brochure.
- Floor W & van der Plas R. 1991. Kerosene stoves : their performance, use and constraints. Joint UNDP/World Bank Energy sector management assistance program.
- Glahe M & Lee R. 1992. Microeconomics. New York, Longmile.
- Graaf JF. 1986. The present state of urbanisation in the South African homelands. University of Stellenbosch.
- Grisso JA. 1993. Making comparisons. The Lancet. Vol.342,pp.157-160.
- Hoek G & Brunekreef B. 1993. Acute effects of a winter air pollution episode on pulmonary function and respiratory symptoms of children. Archives of Environmental Health. Vol.48, No.5, pp.328-335.

- Kahneman D & Tversky A. 1981. The framing of decisions and the psychology of choice. Science. Vol.211, pp.453-458.
- Kahneman D & Tversky A. 1974. Judging under uncertainty; Heuristics and biases. Science. Vol.185, pp.1124-1131.
- Kibel SM, Bass DH, Cywes S. 1990. Five years' experience of injured children. South African Medical Journal. Vol.78, pp.387-391.
- Kibel SM, Joubert G, Bradshaw D. 1990. Injury-related mortality in South African children, 1981-1985. South African Medical Journal. Vol.78, pp.398-403.
- Kirkwood BR. 1991. Acute Respiratory infections. In Feachem RG & Jamison DT (ed.'s) Disease and Mortality in Sub-Saharan Africa. World Bank, Oxford University Press.
- Kossove D. 1982. Smoke-filled rooms and lower respiratory disease in infants. South African Medical Journal. Vol.61, pp.622-624.
- Lancaster K. 1966. Change and innovation in the technology of consumption. American Economic Review. Papers and proceedings of the American Economic Association. Vol.56, pp.14-23.
- Lerer LB. 1994. The epidemiology of fatal childhood burns. South African Medical Journal. Vol.84,p.169.
- MacNamee D. 1993. Health costs. The Lancet. Vol.342, pp.105-106.
- McNiel BJ, Pauker SG, Sox HC, Tversky A. 1973. On the psychology of predictions. Psychological review. Vol.80, No.4, pp.237-251.
- McNiel BJ, Pauker SG, Sox HC, Tversky A. On the elicitation of preferences for alternative therapies. New England Journal of Medicine. Vol.306, No.21, pp.1259-1262.
- National Electrification Economic Study : Phase 1. 1993. Public sector economic impact study team on Financing requirements of national electrification scenarios.
- NELF News. 1993. Newsletter of the National Electrification Forum. No.1, September.
- Ngwenya I. 1993. Power to the people ! Sunday Times. October 31.

- Ozkaynak H. 1993. Review of recent epidemiological data on health effects of particles, ozone and nitrogen dioxide. Proceedings of clean air challenges in a changing South Africa conference. National Association for Clean Air.
- Ostro B. 1993. The association of air pollution and mortality : examining the case for inference. Archives of Environmental Health. Vol.48, No.5, pp.336-342.
- Patetta MJ & Cole TB. 1990. A population-based descriptive study of housefire deaths in North Carolina. American Journal of Public Health. Vol.80, No.9, pp.1116-1117.
- Personal communication : Cape Town ambulance services.
- Personal communication : Alex Pestana.
- Pestana JAX. 1993. Economic impact of cardiovascular disease on the South African economy, 1991. M.Phil. thesis. University of Cape Town.
- Petrie JG, Burns YM, Bray W. 1992. Air pollution. In Fuggle RF & Rabie MA,(ed.), Environmental management in South Africa. Kenwyn, Juta & Co.
- Pityana SM. 1992. The role and place of research and intellectual discourse in the reproduction of social domination in South Africa. Development Southern Africa. Vol.9, No.4, pp.481-486.
- Pouris A. 1986. Price and income elasticities of electricity demand in South Africa. South African Journal of Science. Vol.82, pp.286-288.
- Rowley M. 1993. Council under fire over fees. Cape Times Home Finder. Friday,December 10.
- Runyan CW et al. 1992. Risk factors for fatal residential fires. The New England Journal of Medicine. Vol.327, No.12, pp.859-863.
- Schenker M. 1993. Air Pollution and Mortality. The New England Journal of Medicine. Vol.329, No.24, pp.1807-1808.
- Sheldon TA. 1992. Discounting in health care decision-making: time for change ? Journal of Public Health Medicine Vol.14, No.3,pp.250-256.

- Smith KR. 1988. Air pollution : assessing total exposure in developing countries. Environment. Vol.30, No.10.
- Stansfield SK, Smith GS, McGreevey W. 1992. Injury. Health Sector Priorities Review. Washington DC, The World Bank.
- Terblanche P, Opperman L, Nel R, Pols A. 1993. Prevalence of respiratory illnesses in different regions of South Africa. NACA conference paper.
- Terblanche P, Nel CME, Opperman L. 1992. Health and safety aspects of domestic fuels. Medical Research Council National Programme for Urbanization.
- Terblanche APS, Nel CME, Opperman L, Nyikos H. 1993. Exposure to air pollution from transitional household fuels in a South African population. Journal of exposure analysis and environmental epidemiology. Vol.3, Suppl.1, pp.15-22.
- Terblanche APS et al. 1992. Preliminary results of exposure measurement and health effects of the Vaal Triangle Air Pollution Health Study. South African Medical Journal. Vol.81, pp.550-556.
- Turner CR, Tosen GR, Lennon SJ, Blackbeard PJ. 1990. Eskom's air quality impacts - A regional perspective. Eskom.
- Unpublished document. A review of the South African Energy Policy Research and Training Project. Workshop papers 1-3. Energy for Development Research Centre. University of Cape Town.
- van der Berg S & du Toit J. 1992. The socio-economic impact of energy provision to settlements in rapidly growing metropolitan areas of South Africa, with particular emphasis on electricity. Institute for futures research. University of Stellenbosch.
- van Gass I. 1993. Nature and Determinants of energy and appliance requirements. National Electrification Forum. Report no. WGEU03.
- van Horne JC. 1977. Fundamentals of financial management 3rd ed. Englewood Cliffs, Prentice-Hall.
- Viljoen RP. 1993. Analysis of comparative domestic energy costs in the PWV area. Planning and Energy Research.

- Viljoen RP. 1992. Energy, air quality and the urban poor. EPPIC conference paper.
- von Schirnding YER. 1992. Environmental health. In Fuggle RF & Rabie MA,(ed.), Environmental management in South Africa. Kenwyn, Juta & Co.
- von Schirnding YER & Mokoetle KE. 1991. Assessing the impact of air pollution on health, with special reference to the Johannesburg-Soweto child health respiratory study. NACA conference paper.
- von Schirnding YER, Yach D, Klein M. 1991. Acute respiratory infections as an important cause of childhood deaths in South Africa. South African Medical Journal. Vol.80,pp.79-82.
- Wells RB. 1992. Dangerous pollutants produced by coal combustion. Ematek, CSIR.
- Wibowo D & Tisdell C. 1993. Health, safe water and sanitation : a cross-sectional health production function for Central Java,Indonesia. Bulletin of the World Health Organisation. Vol.71 (2), pp.237-245.
- World Bank. 1993. The World Bank's role in the electric power sector. Washington DC, World Bank.
- World Bank. 1993. Energy efficiency and conservation in the developing world. Washington DC, World Bank.
- Yach D & Townsend GS. 1988. Smoking and health in South Africa. South African Medical Journal. Vol. 73, pp. 391-399.
- Yach D. In press. Paraffin poisoning : Partnership, the key to prevention. South African Medical Journal.
- Zwarenstein M, Vundule C, Bourne D, Laubscher R, Volmink J. In press. Private medical practice in the Republic of South Africa : Description and short term trends.
- Zwi S et al. 1990. Respiratory health status of children in the eastern Transvaal highveld. South African Medical Journal. Vol.78,pp.647-653.