Energy services in low-income urban South Africa: a quantitative assessment

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Introduction

This report forms part of the *Energy efficiency, equity and environment* (E4) project which aims to 'identify opportunities for introducing more efficient and environmentally appropriate uses of electricity and other forms of energy to the urban poor of South Africa, and to develop methods for improving the equity benefits of energy use through such efficiency improvements.' The aim of this report is to gather information for a Least Cost Plan (LCP)[1] so as to identify areas for intervention for energy efficiency policy in low-income urban households.

The report focuses on low-income households in the four metropolitan areas of Gauteng, Cape Town, Port Elizabeth and Durban. Of the 9.9 million people living in these metropolitan areas, 19.7% (1.95 million) fall below the poverty line, representing 38% of the national urban poor.

The study focusses on fuel use in urban poor households for a number of reasons. Firstly, energy is an essential good and, therefore, energy demand is relatively income inelastic. As a result, poor households are spending a substantially higher proportion of their monthly household expenditure on meeting household energy needs than wealthier households. The table below demonstrates this relationship.

Income group expressed in terms of per capita expenditure	*Total fuel expenditure*	*Total h/h expenditure*	*Fuel expenditure as a % of total household expenditure*
<100	66.32	586.12	11%
<200	57.58	1041.42	6%
<300	70.55	1286.51	5%
<400	71.75	1526.78	5%
<500	77.61	1727.91	4%
>500	117.06	3150.95	4%
Average	**96.84**	**2384.31**	**4%**

Total monthly household and fuel expenditure by income group for all metropolitan households
Source: SALDRU (1993)

Secondly, access to electricity (both physical in terms of connection and real in terms of economic access) is highly inequitable in South Africa. As a result, low-income households use cheaper, readily available fuels such as paraffin, candles and coal. Health and safety risks, such as fires, poisonings and respiratory ailments resulting from localised air pollution, are linked to the use of these fuels.

The aim of a LCP is to find the least cost means of meeting demand for services using a mixture of supply side resources and demand side measures. Such measures can benefit both supply utilities and end-users. Electricity supply utilities are faced with increasing peak loads as new electrification occurs. In the face of these increasing peak loads, the options available to these supply utilities are to increase capacity or to shift or reduce the load. Energy efficiency interventions can influence household energy use thus facilitating the reduction or shifting of peak loads. As mentioned previously, the poor are faced with energy bills that consume a disproportionately large part of their monthly household budget. Energy efficiency measures which reduce the energy bill of poor households while improving their health and safety, therefore, can improve the welfare of the poor.

The report has used existing surveys of household energy consumption to analyse:

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1 Least cost energy planning (LCP) is a process which meets the need for energy services with the least cost mix of energy supplies (supply side options) and energy efficiency improvements in end use applications (demand side options). It has been identified as an appropriate means of assessing and evaluating the most applicable energy efficiency strategies for low-income urban households.

- household energy use by fuel type and end-use; and
- thermal performance of low-income housing.

The above information is assessed in terms of a backdrop of socio-economic conditions and access to electricity.

Thermal performance

Clear links have been established between energy consumption and climatic conditions. It has been found that the total energy consumption of households in the colder area of Gauteng is considerably higher than in the temperate areas of Port Elizabeth and Cape Town and the sub-tropical area of Durban. These differences are reflected in the table below.

	Formal electrified	*Formal non-electrified*	*Planned informal*	*Unplanned informal*
Gauteng	3358	5457	5668	4199
Durban and Pietermaritzburg	1935	3156	2665	2069
Cape Town	1942	1561	1461	1392
Port Elizabeth and East London	1252	1098	1007	1013

Average monthly household energy consumption (in delivered MJ)
Source: EPRET (1993) cited in Eberhard & Van Horen (1995)

While these variations in total household energy consumption of delivered energy do reflect differences in heating requirements between the geographical areas, some of the variation can be attributed to differences in the types and costs of fuels used and differences in the efficiencies of appliance/fuel combinations.

The variability of climate also has implications for construction and design. The amount of fuel required for heating purposes can be tempered by using appropriate construction materials and design strategies in residential buildings. Information on the means and fluctuations in climate can be used to determine whether or when a building requires heating and/or cooling to maintain an acceptable level of comfort. In this way, climatic data, specifically the parameter of temperature, together with solar geometry, can be used to select appropriate design strategies and construction materials for building in a specific area.

Few low-income houses in South Africa are constructed using appropriate construction materials or design strategies. In formal housing, the priority has always been to build houses which minimise capital cost. In the process, thermally efficient construction materials and design criteria are sacrificed. Construction materials used in informal housing vary substantially in terms of their thermal performance. Out of necessity, poor urban households use materials that are readily available and low in cost. Housing thus becomes shelter from the harsher weather elements and closure for privacy rather than a comfortable living environment. Iron/zinc was found to be the most common material used in informal housing in all areas with the exception of Durban. Iron/zinc has a high conductivity and thus exhibits poor thermal properties.

There is considerable room for improvement in the thermal performance of low-income formal and informal dwellings. Different strategies need to be targeted at the different dwelling types. For new buildings in the formal housing sector, energy efficient building codes, quality control and innovative delivery systems may alone be appropriate strategies.

Addressing thermal performance improvements in informal housing is a more complex issue. There is a need for practicable, low cost methods of improving the thermal performance of informal housing. Researchers have turned to the use of cardboard as an insulating material in informal housing and low-income formal housing. While the use of cardboard as a means of reducing wind and dust infiltration is a common practice in informal dwellings, there are some practical problems associated with its use. These have been identified by White (1996) and Mehlwana and Qase (1996) and include:

- safety risks (the use of paper and other lightweight materials to insulate shacks is considered a fire hazard in households using candles and paraffin as primary fuels); and
- practical problems such as the difficulty of installing ceilings in shacks where there are no crossbeams to support the ceiling.

In many cases, those households which line their shacks with cardboard, leave the cooking area clear of cardboard in order to reduce the threat of fire. Thus that area of the shack in which the source of heat is generally situated, is uninsulated and much heat is likely to be lost through the walls.

Further issues have been raised around how that cardboard is used. Cardboard placed flat against iron walls provides minimal insulation, whereas fluted cardboard creating air spaces between the iron walling and the interior of the shack, provides much better insulation. In moist areas of South Africa, such as Cape Town, flooring is an important thermal consideration. While some shacks in the Cape Town area were found to have raised timber floors reducing the infiltration of water into the dwelling structure, other shacks had bare floors which when flooded were uninhabitable. Although raised floors may be considered a luxury, it is clear that they have an important role to play in improving the thermal performance of the dwelling structure. There is a need, therefore, to inform informal households how best to insulate, orientate and construct their shacks in an affordable manner. To this end, research and development of appropriate materials is required.

Household energy consumption

The most commonly used fuels in low-income households are paraffin, gas, coal, candles and electricity. The types and combinations of fuels used vary greatly between regions and within areas. The types of fuel used are influenced by regional variations in cost and availability of fuels, household income, perceptions of the safety of fuels and social determinants of fuel use such as practices of fuel sharing and household structure.

Nationally, the most widely used fuel in low-income households is paraffin. The frequency of use of paraffin and other fuels is, however, regionally differentiated. The use of coal is almost entirely specific to Gauteng. Nationally, very low levels of LPG use are experienced. Higher levels of use of LPG are found in Cape Town, Port Elizabeth and Durban, than in Gauteng. The use of candles is greater in Gauteng and Durban than in Cape Town and Port Elizabeth.

The full range of household energy needs includes the following end-uses: cooking, space heating, water heating, lighting, refrigeration, entertainment, and ironing. In many cases in low-income households, some of these needs are not met. Specifically, refrigeration, space heating and entertainment services may be lacking in low-income households. This is influenced predominantly by the types of fuels used in the households and the prohibitive cost of appliances. Furthermore, in the case of space heating, climate has been found to influence consumption patterns. In more moderate coastal climates there is less need for space heating than in cold interior climatic areas (Eberhard & Trollip 1994).

This report focuses on those end-uses which are most commonly met and those requiring the highest energy consumption. These are identified as cooking, space heating, water heating, lighting and entertainment services. Different fuels are used to meet these specific household energy needs and these fuels vary between regions and between electrified and non-electrified households on a regional basis. Typical scenarios of low-income household energy use are presented in the tables below and include the fuels used to meet each end-use and the breakdown of household energy consumption in terms of monthly delivered energy.

	Scenario 1 (Electricity)		Scenario 2 (Electricity & paraffin)		Scenario 3 (Electricity, paraffin & gas)		Scenario 4 (Electricity & coal)	
	Fuel	MJ	Fuel	MJ	Fuel	MJ	Fuel	MJ
Cooking	Elec	797	Para	777	Gas	1176	Coal	4455
Space heating	Elec	468	Para	603	Para	603	Coal	5589
Water heating	Elec	112	Para	344	Gas	294	Coal	1107
Lighting	Elec	151	Elec	174	Elec	174	Elec	174
Entertainment	Elec	79	Elec	52	Elec	52	Elec	52
Monthly h/h energy consumption (delivered MJ)	1 607		1 950		2 299		11 377	

Typical fuel scenarios for low-income electrified households in South Africa

While households using electricity only are found throughout South Africa, the frequency of occurrence varies between metropolitan areas and is linked to provincial levels of electrification. The lowest levels of households using electricity only are found in Port Elizabeth. The use of other fuels in combination with electricity varies substantially between regions. The use of paraffin and electricity is most commonly found in Port Elizabeth and Cape Town. Candles are often used in combination with electricity for lighting needs in Durban and Gauteng. The combination of electricity, paraffin and candles is most prevalent in Durban and, to a lesser degree, Gauteng.

	Scenario 5 (Paraffin)		Scenario 6 (Paraffin & candles)		Scenario 7 (Paraffin & gas)		Scenario 8 (Coal & candles)	
	Fuel	MJ	Fuel	MJ	Fuel	MJ	Fuel	MJ
Cooking	Para	777	Para	777	Gas	1176	Coal	4455
Space heating	Para	603	Para	603	Para	603	Coal	5589
Water heating	Para	344	Para	344	Gas	294	Coal	1107
Lighting	Para	311	Para	185	Para	311	Cand.	124
			& cand.	52				
Monthly h/h energy consumption (delivered MJ)	2 035		1 961		2 384		11 275	

Typical fuel scenarios for low-income non-electrified households in South Africa

Households using paraffin only (scenario 5) are found predominantly in Port Elizabeth and Cape Town, with 77% and 57% of non-electrified households fitting into this scenario respectively. The combination of paraffin and candles (scenario 6) is found in Durban (70% of non-electrified households) and, to a lesser degree, Gauteng (45% of non-electrified households). The combination of paraffin and gas (scenario 7) is found predominantly in Port Elizabeth (11%) and Cape Town (16%), while in Durban, this scenario combined with the use of candles for lighting, is also commonly found (9%). In Gauteng, the combination of coal and candles is prevalent; this may be combined with the use of paraffin in summer. Car batteries may be used for entertainment services in combination with any of the above scenarios for non-electrified households.

The monthly household delivered energy requirements for scenarios 1, 2, 3, 5, 6 and 7 are roughly equivalent. In Gauteng, electricity- and coal-using and candle- and coal-using households have substantially larger monthly delivered energy requirements. Some of this difference in delivered energy may be attributed to regional climatic variations. In the colder Gauteng region, higher space heating requirements are experienced. When comparing cooking and water heating requirements, however, it is evident that not all of the variation in delivered energy can be attributed to climate. The energy requirement for cooking and water heating for coal-using households in Gauteng was found to be 5562MJ as compared with 1121MJ or 1470MJ for paraffin- and gas-using households respectively. This represents a monthly delivered energy requirement in coal-using households four to five times greater than that in paraffin- or gas-using households. The differences in efficiency of coal appliances compared with gas or paraffin appliances is a factor of between 1.5 and 2. This lower conversion efficiency of coal appliances results in coal-using households having to use more fuel to perform the same tasks and can account for further variations in monthly delivered energy requirements.

It is evident from the above analysis that the efficiency of these fuels to perform different tasks varies substantially and that the fuels used in low-income households to meet specific end-uses are often not the most efficient. Furthermore, there are significant health and safety implications associated with the use of coal, paraffin and candles, the most commonly used fuels in non-electrified low-income households. The welfare of low-income households can be improved by managing household fuel use in a way that the most efficient fuels for each specific household energy need are used. Development and energy policy should target and promote household energy management strategies based on efficiency and safety. Such policies will need to take into account the social and economic survival strategies identified as major determinants of current household fuel choices.

There are three significant limitations to the data presented on the breakdown of monthly household energy consumption in the tables above. Firstly, the survey data used to calculate these breakdowns are averages or mean values. Substantial variations in fuel use occur on the micro-scale between households. An appliance/fuel combinations used for the same end-use may be used in different ways, for different lengths of time or at different times and, therefore, the quantities of fuels used may vary substantially between households. The way in which appliances and/or fuels are used depends on a range of variables, including income, geographic location, perceptions and/or knowledge of the energy efficiency of appliances, and social determinants such as household size and structure. For example, space heating requirements vary between areas and the amount of fuel used for space heating will, therefore, vary accordingly. The above scenarios show the breakdown of fuel use for the areas in which the identified fuel combinations are most commonly found and are thus not representative of all households using the fuel combination country-wide.

Secondly, generalised pictures of household energy use, as presented in the typical fuel scenarios, do not take into account the intricacies of fuel switching and multiple fuel use. It has been inferred that households switch between fuels for a number of reasons. For example, in Gauteng it has been found that low-income households switch between coal and paraffin on a seasonal basis to reduce the space heating effect of coal appliances in warmer weather. It is not apparent whether this switching of fuels is a complete process (that is, households switch from using only coal in winter to only paraffin in summer) or whether the use of coal is merely reduced in summer. A further example occurs when electrified households using prepayment meters budget for the consumption of a particular amount of electricity per month and once this has been consumed they may switch to another fuel, for example paraffin, which is easily available on credit.

Finally, while the scenarios are useful indicators of the quantity and breakdown of energy in low-income households, it is difficult to compare the performance of the different fuels in meeting a specific end-use. The scenarios do not reflect the quality or level of service in each case. This highlights the need for qualitative data on the levels of service provided for the substantiation of future comparisons.

Chapter 1
INTRODUCTION

This report forms part of the Energy efficiency and environment (E4) project which aims to 'identify opportunities for introducing more efficient and environmentally appropriate uses of electricity and other forms of energy to the urban poor of South Africa, and to develop methods for improving the equity benefits of energy use through such efficiency improvements.' Least cost energy planning (LCP), a process which meets the need for energy services with the least cost[1] mix of energy supplies (supply side options) and energy efficiency improvements in end use applications (demand side management), has been identified as an appropriate means of assessing and evaluating the most applicable energy efficiency strategies for low-income urban households.

This report forms the preamble to the formulation of a LCP for urban areas in South Africa. It sets out the current status of energy end-use among the urban poor household sector in South Africa in the context of urban poverty and urban restructuring. The main purpose of this paper is to develop models of end-use consumption for the four metropolitan areas mentioned below.

1.1 Methodology

1.1.1 Areas of focus

Urban low-income households residing in the major metropolitan areas of Cape Town, Port Elizabeth, Durban and Gauteng are the focus group of this paper (refer to figure 1.1). Various categories of data were selected and prepared on the basis of being required for the LCP. These categories include national and metropolitan socio-economic data; national and regional climatic data; the types and efficiencies of materials used in the construction of low-income dwellings in the selected urban areas; the level of access to services; and household energy consumption data. The purpose of this paper is to analyse this data and summarise it in a format which will be useful to inform a least cost energy plan.

1.1.2 Survey material

The paper draws from a wide variety of existing surveys, collating and cross-referencing data to formulate a picture of socio-economic factors and end-use consumption in the four study areas. Socio-economic and climatic data is presented broadly for all provinces for ease of adapting models to other urban areas across the country. More detailed information is provided for the selected metropolitan areas. National and metropolitan socio-economic data was drawn from SALDRU (1995), the Central Statistical Services reports (1994) and the different energy consumption studies. Climatic data was drawn primarily from Schulze's (1994) report entitled 'Climate of South Africa: Part 8 - General survey' which collates data from the national Weather Bureau, presenting a national climatic picture. Additional climatic data was obtained from the National Weather Bureau as required. Consumption data was drawn primarily from two types of sources - the energy consumption studies relevant to the four metropolitan areas selected for the study and the South African Labour Development Research Unit's (SALDRUs) Project of Statistics for Living Standards and Development (PSLSD). Data extracted from the study prepared by Rossouw & Van Wyk (1993) was utilised for Port Elizabeth. The studies prepared by Mehlwana & Qase (1996) and Thorne & Qangule (1994) were used for Cape Town. The data for both Gauteng and the Durban Region is based primarily on information presented in the Hoets and Golding (1992) survey. Where necessary, consumption data has been drawn from other sources to validate or augment the findings of the above-mentioned consumption studies.

The appliance/fuel use data presented in these studies is categorised into different dwelling types (formal housing, informal planned and unplanned housing and backyard shacks) and electrified versus non-electrified and utilised to develop models of end use consumption for the four metropolitan areas.

[1] Cost is defined from society's point of view and includes non-financial factors such as environmental impact.

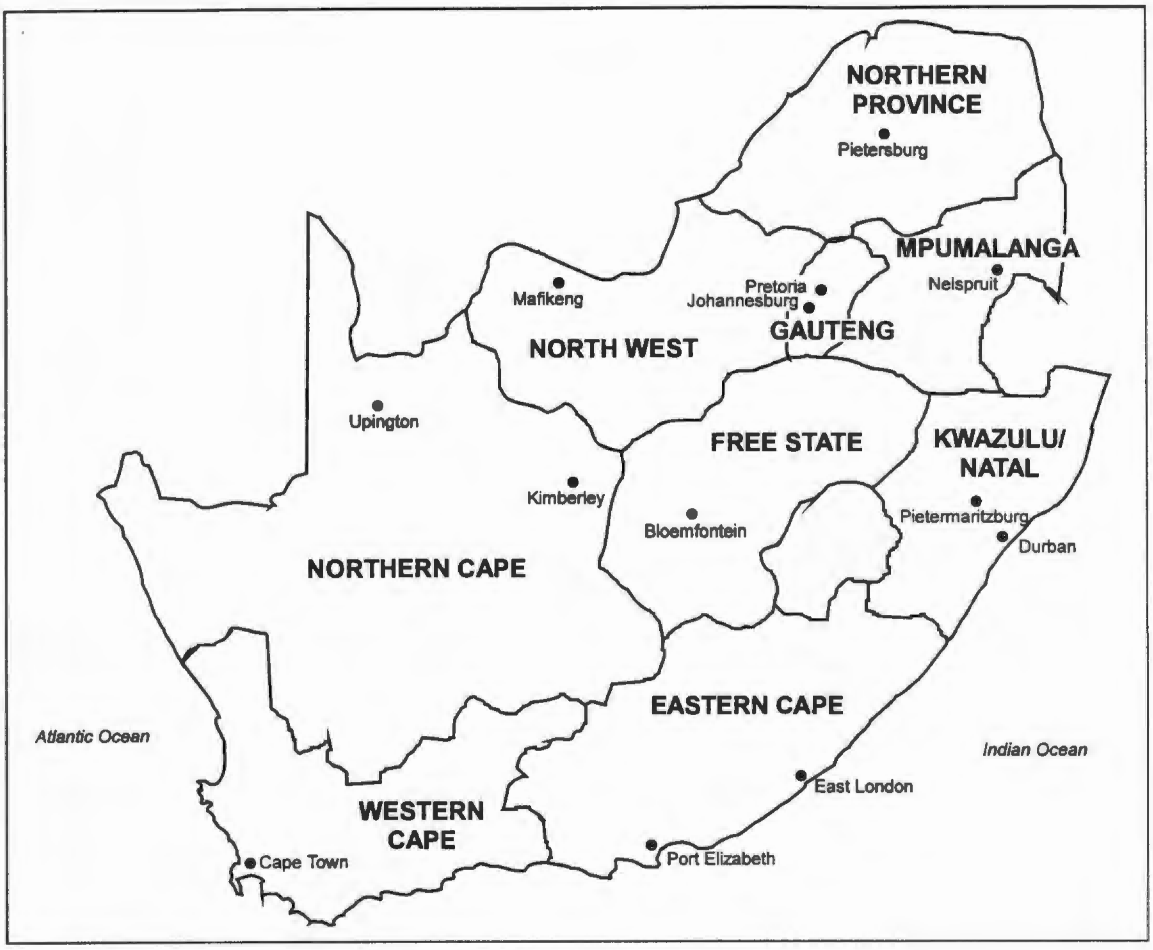

Figure 1.1: South Africa: provinces and major cities

1.1.3 Structure of the paper

Chapter 1 outlines the aim, focus and purpose of this paper and places the selected areas in their national and local context. Chapter 2 outlines the socio-economic perspective of the selected areas. Chapter 3 explores the thermal efficiency of low-income housing, analysing the types of materials used in the construction of low-income housing on an area by area basis and examining their relative efficiencies. Chapter 4 presents quantitative data on the level of access to the services of electricity and water. Chapter 5 provides a comparative analysis of end use energy consumption in the four urban areas.

1.2 Profile of focus group in national context

Table 1.1 indicates the provincial population across the country totalling 38 million in 1993 according to SALDRU (1995) or 40 million in April 1994 according to the Central Statistical Services (1994). The urban and rural distribution of South Africa's population and provincial population densities are also shown in table 1.1. Most of South Africa's urban population reside in the provinces of the Western and Eastern Cape, Kwazulu/Natal, Gauteng and the Free State.

Provinces	Total population		Rural population		Urban population		Population density	Poverty rates
	Mill.	% of total SA pop.	Mill.	% of total SA pop.	Mill.	% of total SA pop.	(people per sq. km)	% of poor households
Western Cape	3.4	9.0	0.5	1.3	2.9	7.7	26.3	23
Northern Cape	0.7	1.9	0.2	0.5	0.5	1.3	2.0	57
Eastern Cape	6.2	16.4	4.2	11.0	2.0	5.3	55.5	78
Free State	2.6	6.9	1.2	3.2	1.4	3.7	20.0	66
Kwazulu/Natal	7.9	20.9	4.9	13.0	3.0	7.9	86.5	53
Gauteng	6.5	17.2	0.3	0.8	6.2	16.4	390.1	19
North West	3.1	8.2	2.1	5.6	1.0	2.6	26.5	57
Mpumalanga	2.7	7.1	1.9	5.0	0.8	2.1	25.5	52
Northern Province	4.7	12.4	4.3	11.4	0.4	1.1	38.2	77
Total	**37.8**	**100**	**19.6**	**51.9**	**18.2**	**48.1**		**52.8**

Table 1.1: Population distribution, density and levels of poverty by province in South Africa

Table 1.1 shows the provincial poverty rate across the country and table 1.2 indicates the distribution of poverty[2] in the country between rural and urban areas. Rural areas have much higher poverty rates than urban areas. However, given that urban areas are supposed to provide easier access to economic opportunities, the rate of poverty in South African urban areas, is alarmingly high. The pervasiveness of poverty in the different areas has implications for regional energy consumption patterns.

	Population (millions)	Poverty rates (%)
Rural	20.3	73.3
Urban	17.7	28.8
All	38.0	52.8

Table 1.2: Distribution of poverty by rural/urban classification, 1993
Source: adapted from SALDRU (1995)

As shown above, of the 17.7 million people residing in urban areas, 28.8% (5.1 million) fall below the poverty level. Of the 9.9 million people living in the metropolitan areas of Cape Town, Gauteng (which incorporates Johannesburg), Durban and Port Elizabeth, 19.7% (1.95 million) fall below the poverty line. Thus, the poor living in the metropolitan areas cited above represent 38% of the national urban poor.

1.3 National climatic variables

Climatic variables have significant implications for both the appropriateness of materials used in the construction of dwellings and energy use patterns (see chapter three). The relevant weather design criteria are:

- rainfall;
- wind speed and direction;
- relative humidity;

[2] Poverty is defined as the poorest 40% of households in the country which results in a cut-off expenditure level of R301.00 per month per 'adult equivalent' (SALDRU 1995). This level coincides roughly with the ranges of between 39% and 42% of people falling below the poverty line produced by minimum food need indicators and can also be compared with the per adult equivalent household subsistence level (HSL) with a cut-off expenditure level of R251.1 per month.

- solar radiation; and
- temperature.

This section presents the national climatic picture in terms of annual means in rainfall and temperature. More detailed information on the annual means and seasonal fluctuations in rainfall, temperature, wind, and relative humidity is provided for the four urban centres which have been identified as the focus of this study.

1.3.1 Rainfall

1.3.1.1 Mean annual rainfall

From the mean annual rainfall distribution (figure 1.2), one can distil the main features of the national rainfall picture. These features are that firstly, rainfall decreases longitudinally from more than 800mm in the east to almost complete aridity in the west, with the 400mm isohyet dividing South Africa into wetter eastern and drier western parts (Tyson 1986). Secondly, orographic features have a marked effect on national rainfall. This effect is demonstrated in the Western Cape Province, where the average rainfall over the coastal plateau is approximately 400mm, but increases to well over 2 000mm on the mountain ranges.

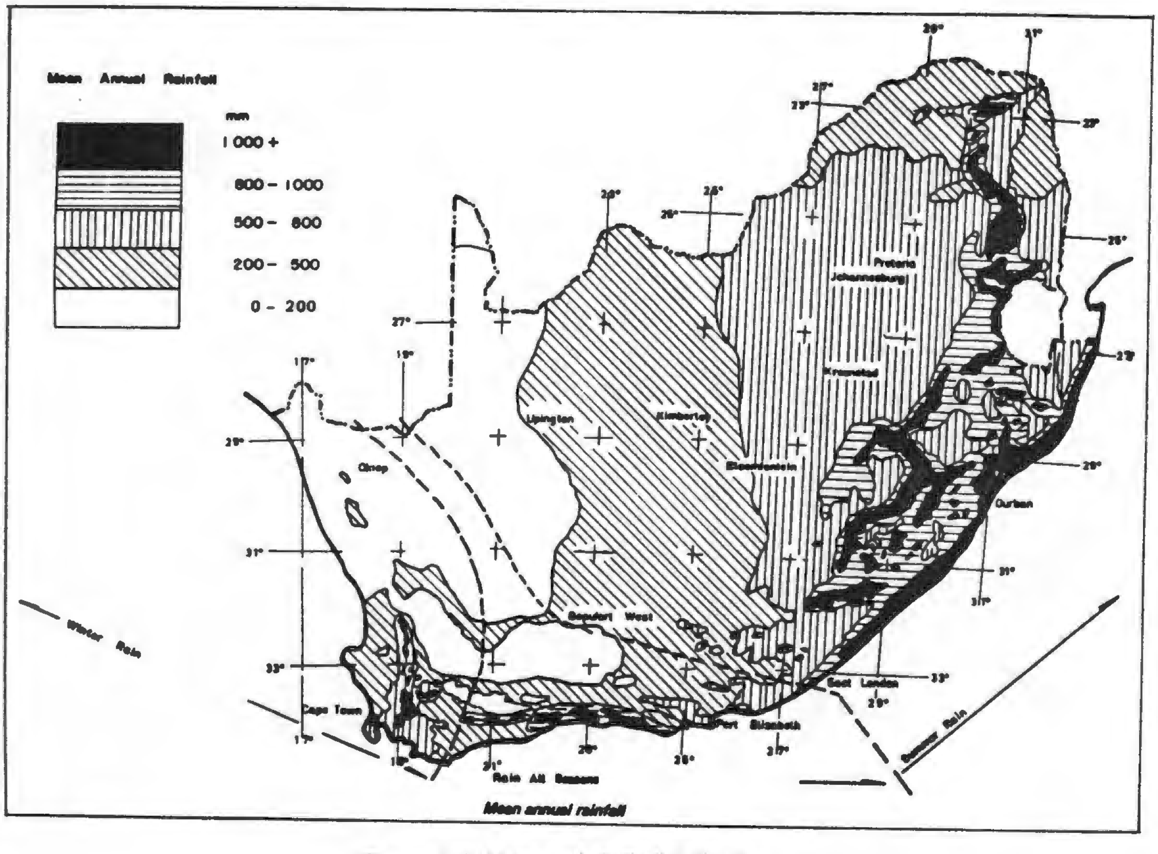

Figure 1.2: Mean rainfall distribution

1.3.1.2 Seasonality of rainfall

Figure 1.3 expresses the average amounts of rainfall for the summer half-year (October to March) as a percentage of the average annual rainfall, demonstrating the highly seasonal nature of most of South Africa's rainfall. Precipitation over the interior northern regions of South Africa follows an annual cycle and is almost entirely a summer phenomenon, with more than 80% of the annual rainfall falling between October and March (Tyson 1986). Westwards, toward the coast, especially to the south and south-west, the quota of winter rainfall is greater. There is a noticeably sharp transition to purely winter rainfall, which is demonstrated by the concentration of lines on either side of the 50% summer rainfall line. The winter rainfall zone (that is, winter rainfall greater than 80% or conversely, summer rainfall less than 20%) is confined to the extreme south-west corner of South Africa. The southern coast of the Western and Eastern Cape and the adjacent interior regions receive rainfall throughout the year. The annual variation of precipitation can be classified into four types (refer to figure 1.4).

- The mediterranean type, for example Cape Town. This type has a very pronounced maximum in winter. Figure 1.4 shows the winter peak in the annual variation of precipitation for Cape Town.
- The type where rainfall occurs in all seasons, for example Port Elizabeth and Uitenhage. Note in figure 1.4 that rainfall occurs in all seasons with a well-marked double-maximum in February-March and September-November.
- The monsoonal type with a single pronounced maximum in mid-summer (Pretoria and Johannesburg).
- The monsoonal type with a single maximum in late summer (March), for example Upington (Schulze 1994).

Figure 1.3: Seasonal rainfall expressed as the average amount of rainfall for the summer half-year as a percentage of average annual rainfall
Source: Schulze (1994)

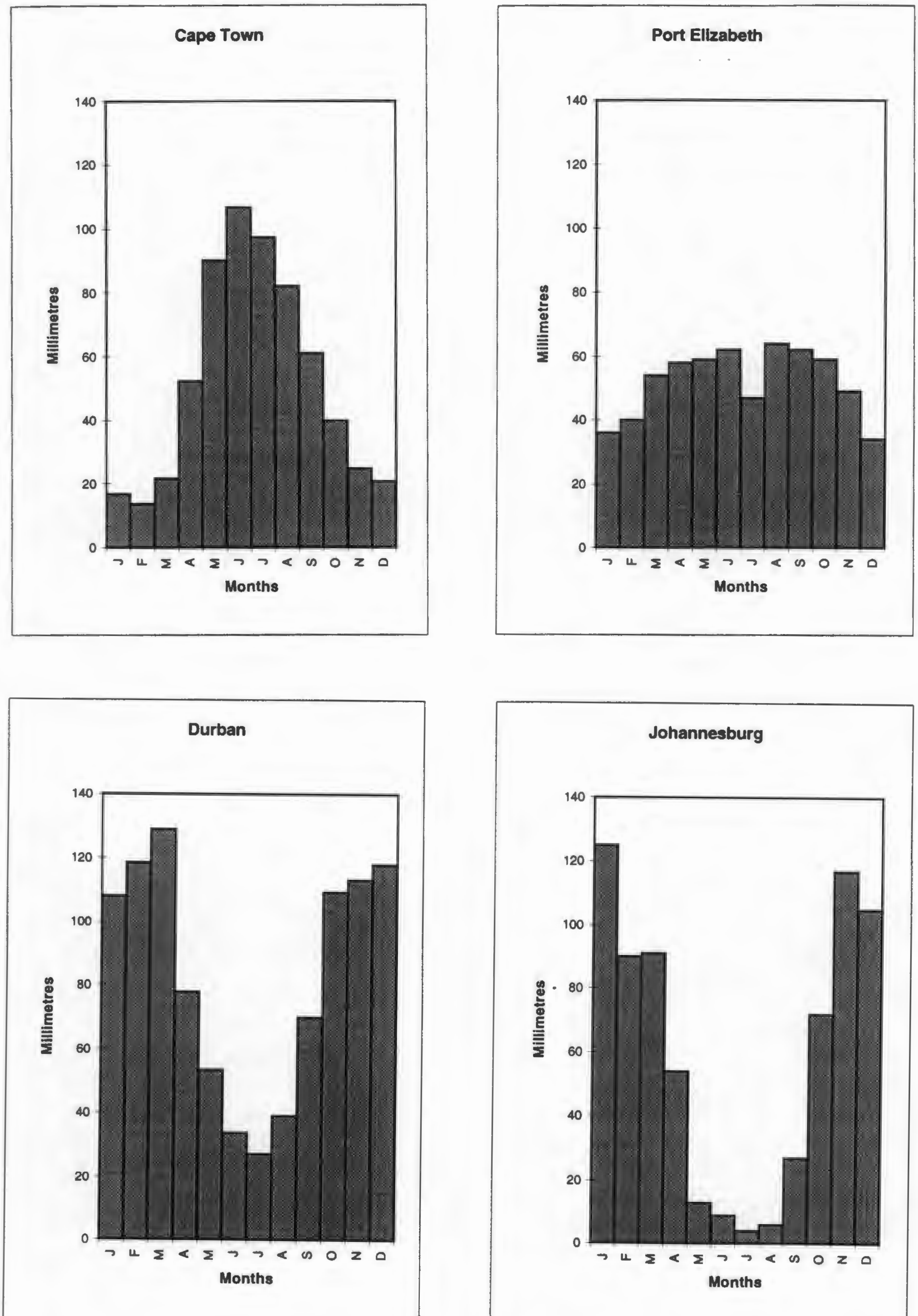

Figure 1.4: Average monthly rainfall
Source: Schulze (1994)

1.3.2 Temperature

Surface air temperature is greatly influenced by altitude and land configuration. South Africa 'extends through about 20 degrees of latitude, that varies from sea-level to a plateau of about 1250m and to mountains exceeding 3 000m in height' (Tyson 1986:7). Thus, the range of temperature conditions in South Africa is considerable.

1.3.2.1 Annual temperatures

Figure 1.5 shows the mean annual temperatures across South Africa. These are computed as the mean of the 12 mean monthly values. On the west coast the annual mean temperature is about 15°C and on the east coast at the same latitude (viz. 29°S), about 21°C, a difference of 6°C. This can be ascribed to the influence of the cold Benguela current off the west and the warm Augulhas current off the east coast. The lowest mean temperatures, below 15°C, are found along the great escarpment, whilst the highest mean temperatures are encountered in the Kalahari and in the Northern Province.

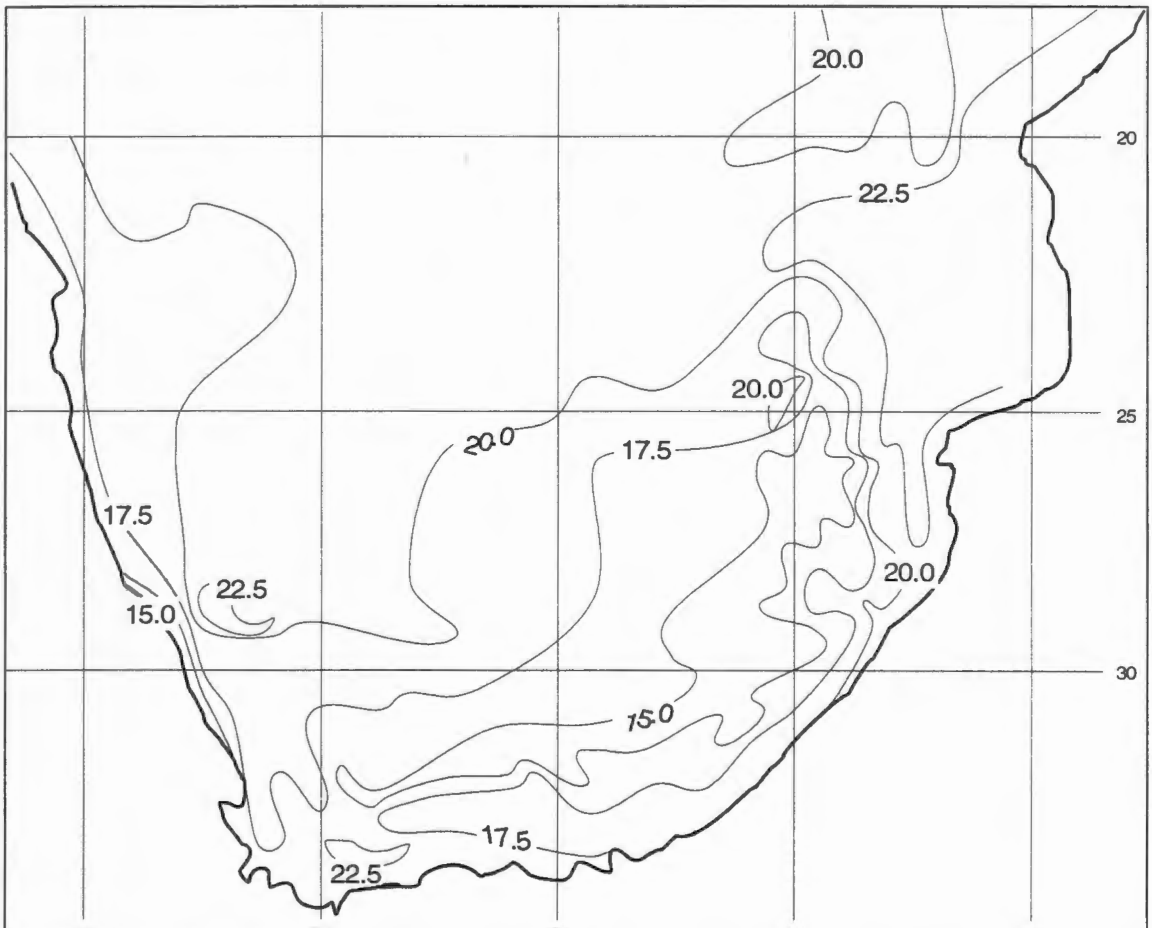

Figure 1.5: Real mean annual temperature
Source: Schulze (1994)

1.3.2.2 Seasonal temperature variations

The annual temperature change over South Africa is demonstrated for selected metropolitan areas in figure 1.6. Here, the mean annual temperature is represented as a straight horizontal line; the mean diurnal range in temperature is shown by the thick black vertical columns which connect the points of mean daily maximum and mean daily minimum temperature; and daily mean temperature is shown by a black curve through the midpoints of the black columns.

As a result of the radiative effect in clear weather, the daily range of temperature is very much conditioned by the incidence of cloud. The daily range increases from summer to winter in the summer rainfall zone (for example, Johannesburg), whilst in the Eastern Cape Province (for example, Port Elizabeth), the range shows very little variation throughout the year. In the winter rainfall zone (for example, Cape Town), the range is largest in summer and least in winter.

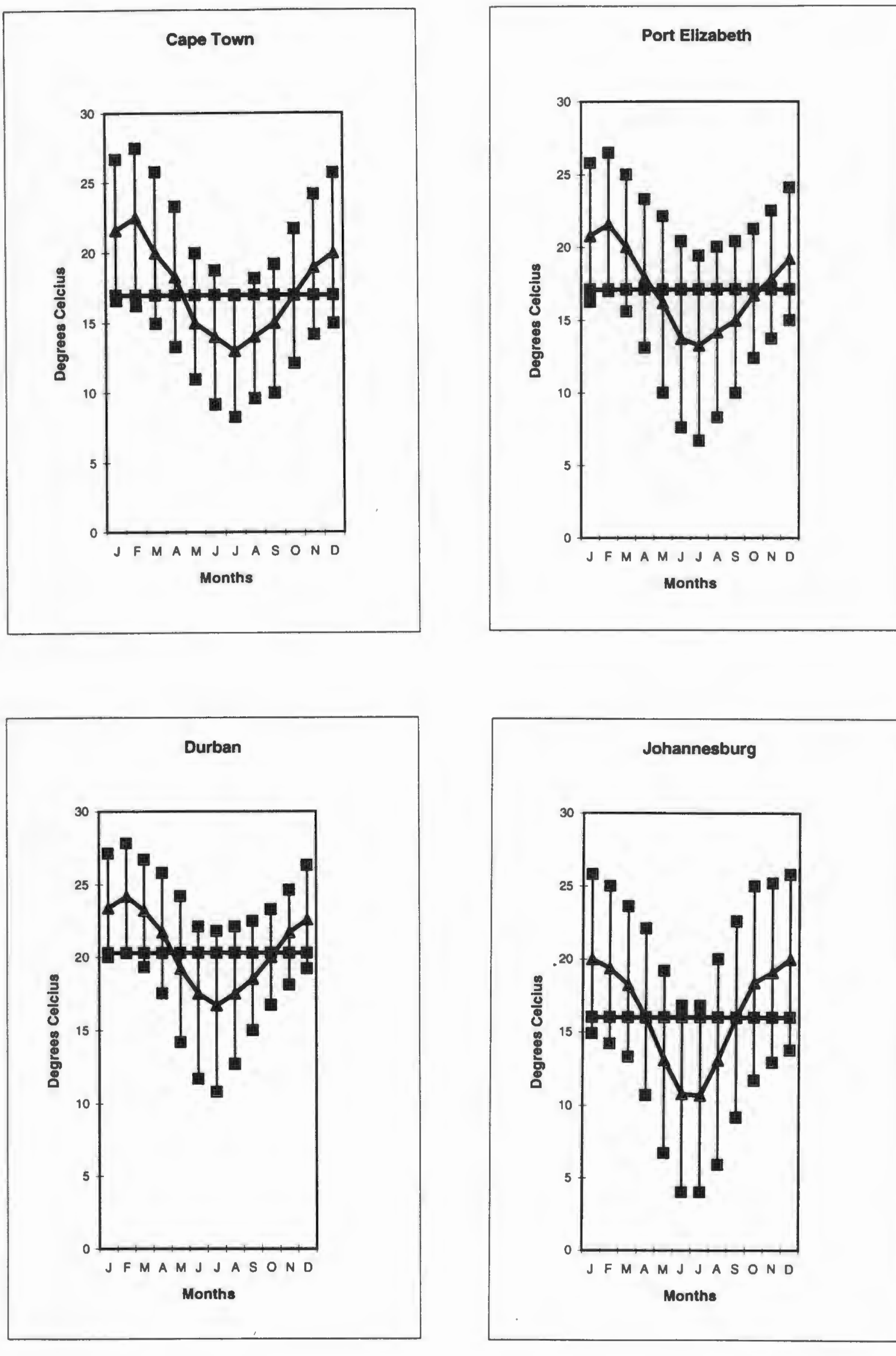

Figure 1.6: Seasonal temperature variations in selected metropolitan areas

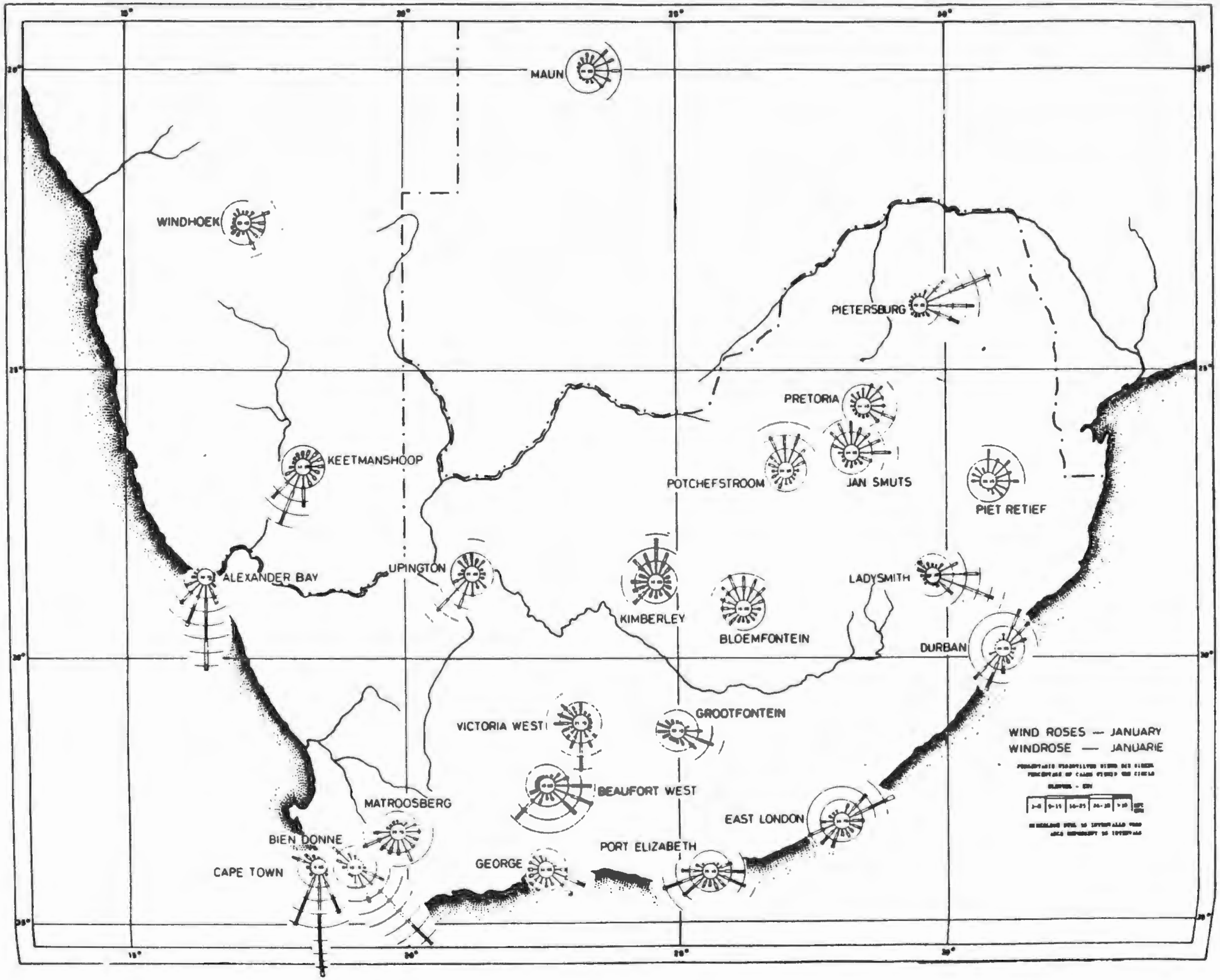

Figure 1.7: Summer wind regime
Source: Schulze (1994)

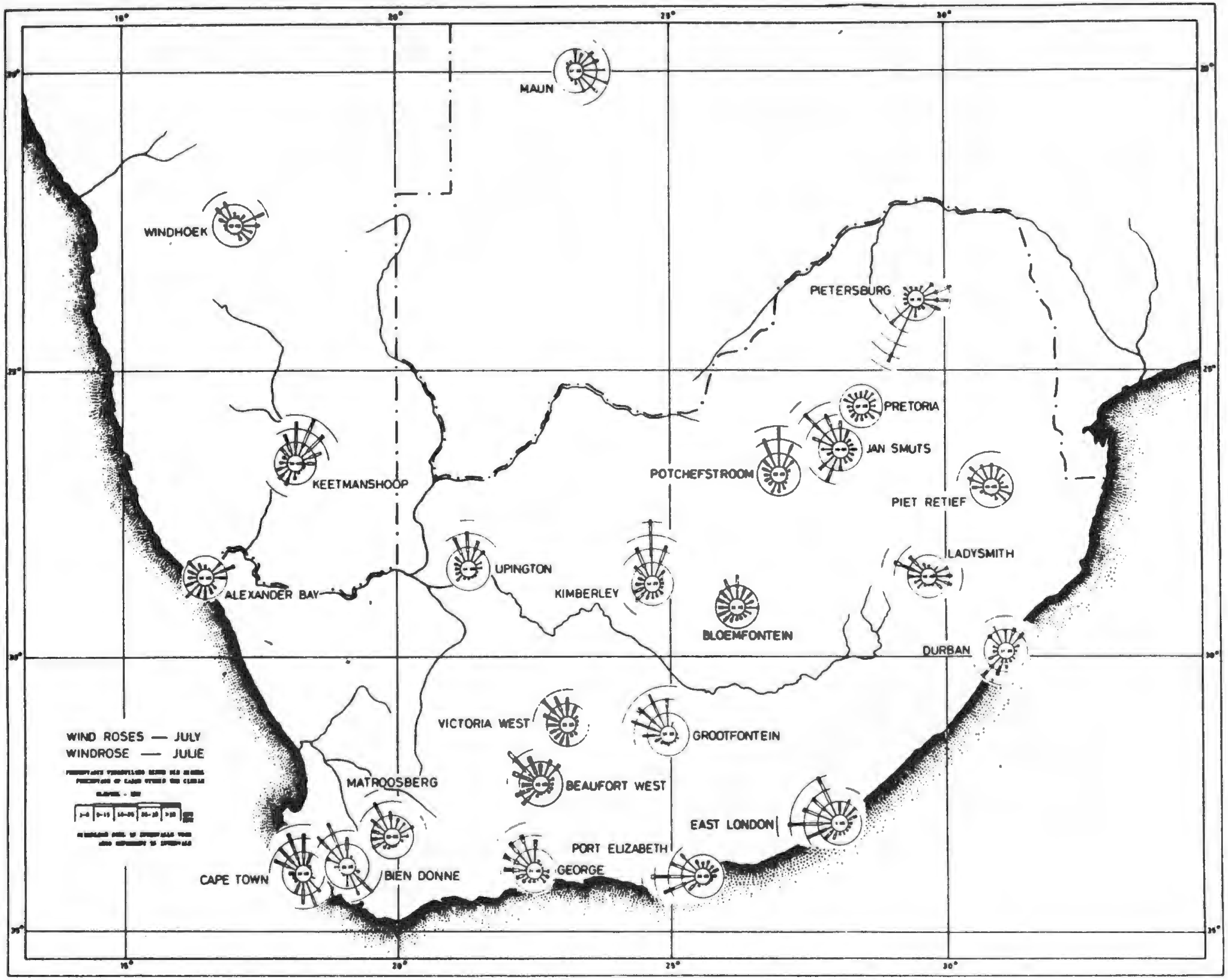

Figure 1.8: Winter wind regime
Source: Schulze (1994)

1.3.3 Wind

Figures 1.7 and 1.8 show the national wind picture for summer and winter. Wind roses show the relative wind frequency from 16 directions, classified in certain velocity intervals. These two figures indicate the main seasonal difference in the wind regime at each wind recording station.

The wind conditions in selected metropolitan areas of Cape Town, Port Elizabeth, Durban, Pretoria and Johannesburg are detailed below.

In Cape Town, strong southerly winds prevail in summer, while rain-bearing north-westerly winds predominate in winter.

In Port Elizabeth, as in many other coastal stations, there is a tendency for the prevailing winds to blow with an off-shore component in winter and on-shore in summer. Winds blow from the north-westerly and westerly sector in winter and the south-easterly and south-westerly sector in summer.

At Durban, the winds in winter are reduced to half their summer frequency. In winter, there are light north-westerly winds and calm conditions, while in summer, south-westerly and north-easterly winds prevail.

Johannesburg is characterised by northerly winds in summer and south-westerly and north-easterly winds in winter.

Site	*Mean wind speed (m/s)*
Cape Town	4.0
Port Elizabeth	4.1
Durban	3.3
Johannesburg	3.1

Table 1.3: Mean wind velocities at selected sites
Source: Diab (1979) cited in Eberhard & Trollip (1993)

1.3.4 Relative humidity

Relative humidity represents the percentage degree of saturation (100 x vapour pressure/ saturation vapour pressure) and is the direct measure of the degree of moistness of the atmosphere irrespective of its temperature (Schulze 1994).

Figure 1.9 compares the average summer and winter relative humidities in Durban, Cape Town, Johannesburg and Port Elizabeth. It shows that relative humidities are much higher in both summer and winter at coastal stations than in the interior, demonstrating the significant influence of the oceans on atmospheric moisture content. Figure 1.9 also reflects the seasonality of rainfall, showing that Cape Town falls into the winter rainfall zone, Johannesburg and Durban into the summer rainfall zone and Port Elizabeth into the zone of rainfall all year round.

Figure 1.10 gives a more detailed picture for the four stations of Cape Town, Durban, Port Elizabeth and Johannesburg, showing the annual march of relative humidity.

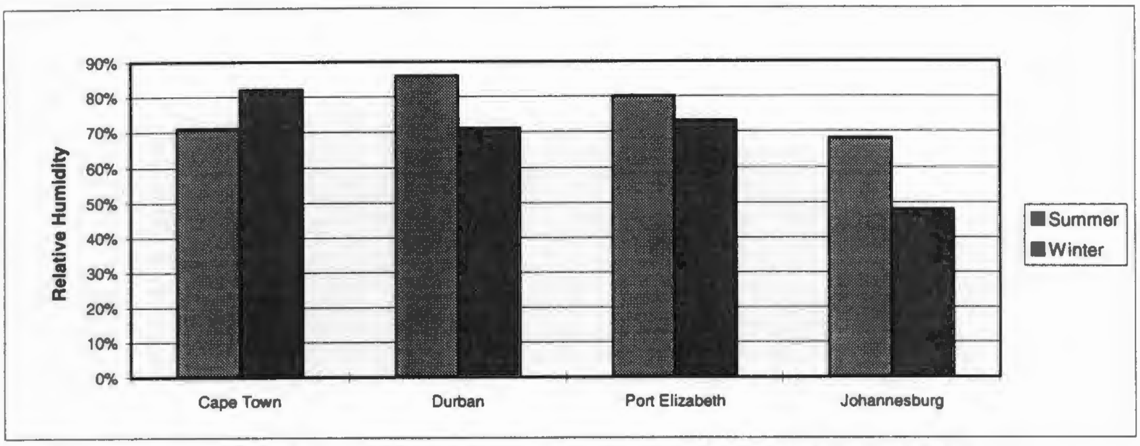

Figure 1.9: Comparison of mean summer and winter relative humidities in selected metropolitan areas
Source: adapted from Schulze (1994)

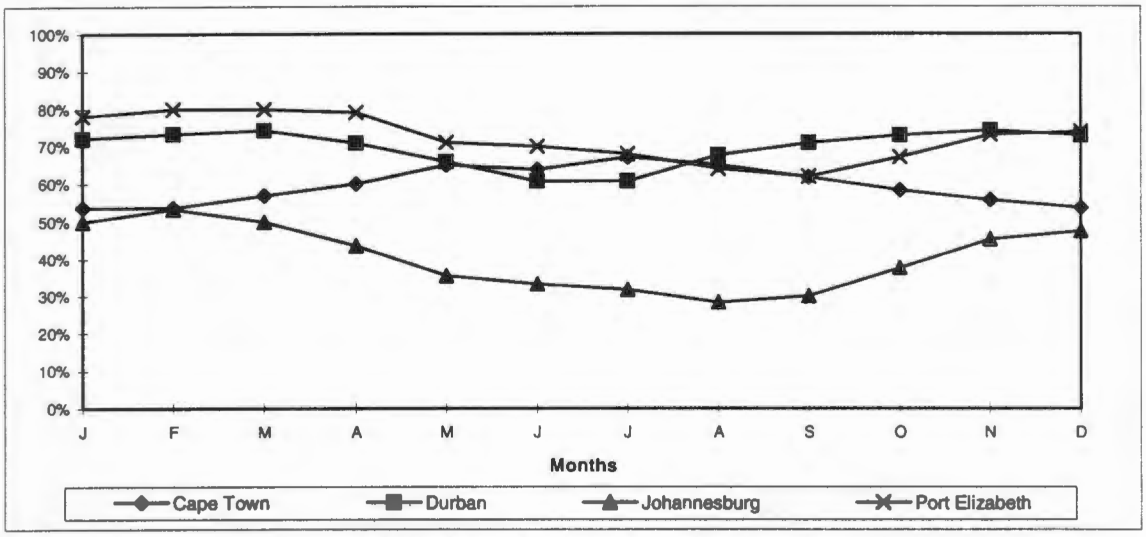

Figure 1.10: Annual march of relative humidity
Source: adapted from Schulze (1994); Weather Bureau (1996)

1.3.5 Solar radiation

Table 1.4 below shows both the global[3] and diffuse[4] mean daily radiation (Wh m^{-2} day^{-1}) for the four focus areas of this paper.

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3 Global radiation includes direct radiation from the sun, radiation reflected from the ground and sky diffuse radiation.

4 Diffuse radiation is the component of solar radiation diffused by the atmosphere.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct	Nov	Dec.
Cape Town												
Global	7956	7177	5887	4207	2946	2390	2684	3462	4707	6291	7552	7952
Diffuse	1836	1636	1447	1250	1010	871	979	1250	1670	1888	2145	2076
Port Elizabeth												
Global	7011	6228	5130	4002	3073	2655	2896	3642	4606	5793	6722	7216
Diffuse	2269	2052	1617	1221	919	763	818	1125	1605	2005	2308	2322
Durban												
Global	5527	5395	4891	3993	3283	3033	3170	3616	4022	4768	5150	5740
Diffuse	2428	2140	1759	1312	984	794	885	1156	1641	2040	2253	2397
Pretoria												
Global	6346	5940	5293	4574	4177	3908	4142	4909	5748	6236	6377	6908
Diffuse	2494	2389	1968	1469	971	824	860	1057	1419	1764	2233	2308

Table 1.4: Mean daily global and diffuse solar radiation (Wh m^{-2} day^{-1})
Source: Eberhard (1990)

1.4 Regional climatic characteristics

As has been demonstrated above, South Africa displays a wide variety of climatic conditions across its expanse. Figure 1.11 summarises the national climatic picture, classifying the southern African climate into six broad climatic zones.

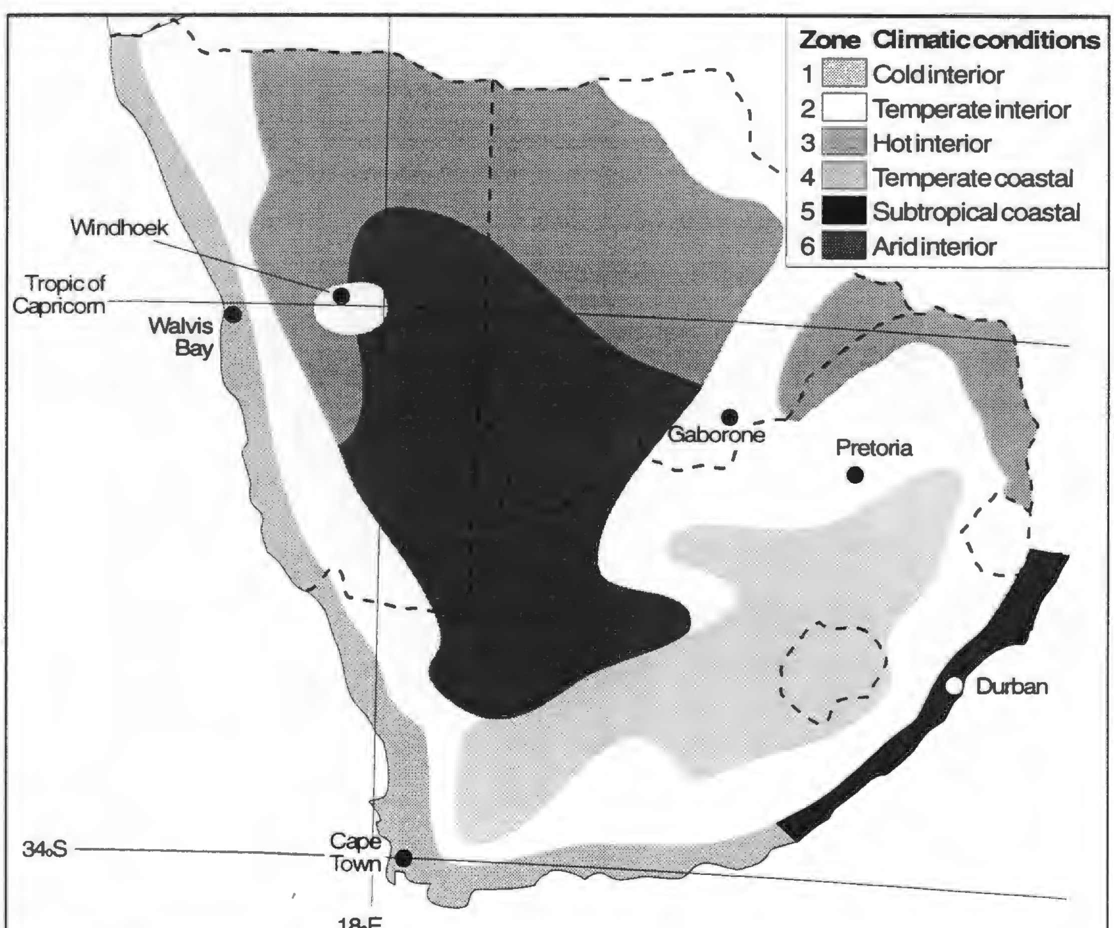

Figure 1.11: Climatic zones of South Africa
Source: adapted from Meyer (1983)

The areas focused on in this paper fall into three of the broad climatic zones: temperate coastal, sub-tropical coastal and cold interior. These climatic zones can be used to give a broad guide to principles of construction.

Chapter 2
SOCIO-ECONOMIC PROFILES OF THE POOR IN SELECTED URBAN AREAS

2.1 Introduction

As mentioned in chapter one, the survey data compiled by Hoets and Golding (1992), Rossouw and van Wyk (1993) and Mehlwana and Qase (1996) and used to establish patterns of consumption among the urban poor, was presented and analysed by dwelling type. In order to gain understanding of the socio-economic conditions represented by the different dwelling types, this chapter provides detailed socio-economic profiles for households in those areas selected to represent the urban poor of Johannesburg, Durban, Cape Town and Port Elizabeth. Indicators such as household size and composition, household head by gender, household income and expenditure, per capita income and levels of employment and dependency are analysed to establish the link (or lack thereof) between dwelling type and levels of poverty in the sample areas.

Traditionally, energy consumption patterns (such as types and quantities of fuels used) have been linked to levels of income. While income is a significant factor influencing the patterns of energy consumption, other variables are also important. These variables include the structure and composition of the household and the gender and age of the household head. The socio-economic variables are thus further analysed in terms of their implications for household energy consumption.

This chapter also makes qualitative statements about the focus group and areas under consideration. Qualitative data includes discussions around movements of people, the sharing of fuels and appliances, attitudes and perceptions of fuels and their use and social trends which explain patterns of energy use and provide a means of predicting future usage patterns.

2.2 Dwelling types

Housing is categorised into four main groups in the consumption surveys. These categories are formal dwellings and planned informal, unplanned informal and backyard shacks.

Formal housing is categorised as conventional housing built of accepted building materials in formal, planned townships.

Informal settlements are generally defined in terms of the building materials used in construction. These building materials, however, 'vary considerably in origin, nature and durability, and include wattle-and-daub, mud bricks, corrugated iron, plywood sheeting and sometimes more orthodox materials such as concrete blocks and clay bricks' (Urban Foundation 1991). Discrepancies in categorisation come into play when defining planned versus unplanned informal settlements. While in some surveys the defining criteria are access to services and legallity of settlement, others establish minimum criteria of level of service as the defining criterion.

Planned informal settlements are commonly defined as official site-and-service schemes. These are legally established townships offering legal tenure and widely differing levels of service. Services range from basic pit latrines and communal water points, to relatively sophisticated water-borne sewerage and piped water to individual stands. Mehlwana and Qase (1996) use the above definition as a means of distinguishing between planned and unplanned settlements. Planned informal dwellings are defined as site-and-service settlements with legal tenure, while unplanned informal settlements are defined as those dwellings without access to services. Hoets and Golding (1992) take this one step further, evaluating site-and-service schemes in terms of level of access to running water and provision of permanent toilets for each dwelling. The minimum standards for planned settlements to satisfy the criteria are street taps and pit latrines/chemical toilets. Settlements where only one or none of the criteria were met were considered to be unplanned.

According to the Urban Foundation (1991), backyard shacks are classified as informal structures erected on residential properties in formal legal townships. Outbuildings, such as formally constructed structures such as garages, sheds or even backyard rooms, may be included in this category as they offer unconventional and often unauthorised shelter to households not accommodated in formal structures. Mehlwana and Qase (1996) use the above definition of backyard shacks to select their sample households.

2.3 Household size and composition[1]

Household size and poverty are closely related. Large households with many dependants are much more likely to be poor. In South Africa, the average household size among the poor is 5.9, while among the non-poor it is only 3.5 (SALDRU 1995)[2]. Tables 2.1 to 2.3 below show the size and structure of households in the areas selected to represent Johannesburg, Port Elizabeth, Durban and Cape Town.

	Johannesburg	*Port Elizabeth*	*Durban*	*Cape Town*
Adults	2.90	3.15	3.55	2.49
Children	1.53	2.06	1.37	1.97
TOTAL	**4.43**	**5.21**	**4.92**	**4.46**

Table 2.1: Comparison of household size and composition: all households
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg	*Port Elizabeth*	*Durban*	*Cape Town*
Adults	2.74	3.46	3.85	2.73
Children	1.20	2.39	1.53	2.17
TOTAL	**3.94**	**5.85**	**5.38**	**4.90**

Table 2.2: Comparison of household size and composition: formal housing
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg		*Port Elizabeth*			*Durban*	*Cape Town*	
	PI	*UI*	*PI*	*UI*	*B/Y*	*I*	*I*	*B/Y*
Adults	3.00	2.89	2.85	3.35	2.24	3.27	2.16	2.12
Children	1.67	1.59	1.74	2.07	1.60	1.23	1.64	2.28
TOTAL	**4.67**	**4.48**	**4.59**	**5.42**	**3.84**	**4.50**	**3.80**	**4.40**

Table 2.3: Comparison of household size and composition: planned and unplanned informal housing and backyard shacks
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

Tables 2.1 to 2.3 above show the larger household sizes in Port Elizabeth and Durban than in Johannesburg and Cape Town. This reflects the higher poverty rates experienced in these provinces as indicated in chapter one. No clear trends exist with regard to variations in household size between the different dwelling types. In Johannesburg, informal houses have larger household sizes, while in Port Elizabeth, Cape Town and Durban larger household sizes are found in formal than in informal dwelling types. It is impossible, therefore, to establish a link between dwelling type and poverty based on the criterion of household size.

1 No definitions of household were provided in any of the studies used and, therefore, the comparability of data is brought into question.

2 These figures refer to all South African households in both rural and urban areas.

2.4 Household head

Household structure and poverty are also linked. The poverty rates among female headed households[3] have been found to be much higher than for households with a resident male head (SALDRU 1995). In a survey of all South African households (both rural and urban), SALDRU (1995) found that female headed households have a 67.5% poverty rate[4], while the poverty rate is only 43.5% among families with a resident male head.

Furthermore, appliance acquisition and patterns of energy consumption are influenced by gender and age of household head. For example, it has been stated that males and females have different perceptions of fuels and the safety of their use and thus use fuels differently (White 1995a, Mehlwana & Qase 1996). Furthermore, it is hypothesised that women would give labour saving devices, such as washing machines and refrigerators, higher priority than would men. White (1995b) found that younger women were more likely to substitute electricity for other fuels due to the perceived modernity of the fuel. Thus, the gender and age of the household head has a significant influence on fuel use patterns.

Tables 2.4 to 2.6 demonstrate the gender composition of household head in the areas selected for survey.

	Johannesburg	*Port Elizabeth*	*Durban*	*Cape Town*
Males	72	52.3	63	56.3
Females	28	47.7	37	43.7

Table 2.4: Percentage of male and female head of households: all households
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg	*Port Elizabeth*	*Durban*	*Cape Town*
Males	67	55.2	59	55
Females	32	44.8	41	45

Table 2.5: Percentage of male and female head of households: formal housing
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg		*Port Elizabeth*			*Durban*	*Cape Town*	
	PI	*UI*	*PI*	*UI*	*B/Y*	*I*	*I*	*B/Y*
Males	70	73	47.9	69.2	40	67	58.4	54
Females	29	26	52.1	30.8	60	33	41.6	46

Table 2.6: Percentage of male and female head of households: planned and unplanned informal housing and backyard shacks
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

Tables 2.4 to 2.6 show that a much higher proportion of households sampled in Port Elizabeth and Cape Town than in Durban and Johannesburg were female-headed. No consistent conclusion can be drawn with regard to variations between dwelling type.

2.5 Household income and expenditure

Household income and expenditure gives a broad indication of the standard of living of households. Tables 2.7 to 2.9 show the nominal income and expenditure[5] of poor households residing in the metropolitan areas of Johannesburg, Port Elizabeth, Durban and Cape Town.

3 Female-headed households are defined in the SALDRU (1995) study to include those households both where the female is officially the head and where the female is the head in practise. No definitions are presented for *female-headed household* in the other studies used and, therefore, comparability is brought into question.

4 As in chapter one, *poverty* is defined as the poorest 40% of households in the country.

5 The mean income and expenditure levels given in tables 2.7 to 2.9 are for the base years of 1992 (Johannesburg and Durban), 1993 (Port Elizabeth) and 1995 (Cape Town).

	Johannesburg	Port Elizabeth	Durban	Cape Town
Average income (R's)	945	828	1119	1 277
Average expenditure (R's)	706	553	1072	*

Table 2.7: Average household income and expenditure: all surveyed households
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg	Port Elizabeth	Durban	Cape Town
Average income (R's)	1458	996	1342	1 550
Average expenditure (R's)	981	672	1263	*

Table 2.8: Average household income and expenditure: formal surveyed housing
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg		Port Elizabeth			Durban	Cape Town	
	PI	UI	PI	UI	B/Y	I	I	B/Y
Average income (R's)	829	782	688	570	595	914	914	923
Average expenditure (R's)	646	616	463	356	345	896	*	*

Table 2.9: Average household income and expenditure: planned and unplanned informal housing and backyard shacks sampled in selected areas of Johannesburg, Port Elizabeth, Durban and Cape Town
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

Tables 2.7 to 2.9 above show that the lowest household incomes are consistently found in Port Elizabeth for all dwelling types (this reflects the higher levels of poverty in the Eastern Cape as shown in chapter one). The highest incomes are found in formal housing in Cape Town and Johannesburg, while among informal households, the highest incomes are found in Cape Town and Durban. It is important to note that the mean values used above are biased by the extremes and that in a large number of households, expenditure is greater than income. In Johannesburg, 33% of all households (27% of formal, 34% of planned informal and 35% of unplanned informal households) and in Durban, 46% of all households (44% of formal and 48% of informal households) are spending more than they earn. No such analysis exists for the areas of Port Elizabeth and Cape Town.

2.6 Per capita income

Household income and expenditure levels give a broad indication of socio-economic status. Per capita income is, however, a more realistic indicator of household income, accounting for variations in household size and, therefore, alluding to levels of dependency and the economic burden of the household wage earners. The per capita income levels given in table 2.10 are for the base years of 1992 (Johannesburg and Durban) and 1993 (Port Elizabeth).

	Total	Formal	Informal		Backyard shacks
			Planned	Unplanned	
Johannesburg	286	478	228	239	*
Port Elizabeth	154	165	145	101	156
Durban	334	384	288		*

Table 2.10: Per capita income for all housing types
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

Table 2.10 above shows the relationship between dwelling type and levels of poverty as a function of per capita income. Formal houses have higher per capita incomes than informal dwellings, thus indicating a lower level of poverty among households living in formal dwellings. Figure 2.10 also demonstrates the variations in per capita income between the different metropolitan areas, thus reflecting provincial variations in poverty. All households in Port Elizabeth show much lower per capita incomes. There is a small variation in per capita incomes in the different dwelling types in Port Elizabeth which should be reflected in the patterns of energy consumption in chapter five.

2.7 Energy expenditure

Energy expenditure data below are presented in two ways: by income group and by dwelling type.

2.7.1 Energy expenditure by income group

Energy is an essential good and, therefore, as income increases the demand for energy increases more slowly. Tables 2.11 to 2.13 demonstrate this income inelasticity of energy demand.

Income group expressed in terms of per capita expenditure	*Total fuel expenditure*	*Total h/h expenditure*	*Fuel expenditure as a % of total household expenditure*
<100	66.32	586.12	11%
<200	57.58	1 041.42	6%
<300	70.55	1 286.51	5%
<400	71.75	1 526.78	5%
<500	77.61	1 727.91	4%
>500	117.06	3 150.95	4%
Average	**96.84**	**2 384.31**	**4%**

Table 2.11: Total monthly household and fuel expenditure by income group for all metropolitan households
Source: SALDRU (1993)

Income group expressed in terms of per capita expenditure	*Total fuel expenditure*	*Total h/h expenditure*	*Fuel expenditure as a % of total household expenditure*
<100	73.67	614.92	12%
<200	63.59	1 180.56	5%
<300	72.88	1 396.35	5%
<400	77.24	1 701.74	5%
<500	81.44	1 847.31	4%
>500	120.80	3 257.76	4%
Average	**104.74**	**2 647.39**	**4%**

Table 2.12: Total monthly household and fuel expenditure by income group for electrified metropolitan households
Source: SALDRU (1993)

Income group expressed in terms of per capita expenditure	Total fuel expenditure	Total h/h expenditure	Fuel expenditure as a % of total household expenditure
<100	53.78	554.93	10%
<200	49.02	843.24	6%
<300	65.69	1 057.07	6%
<400	57.18	1 061.90	5%
<500	62.63	1 261.15	5%
>500	60.03	1 524.03	4%
Average	**57.94**	**1 075.26**	**5%**

Table 2.13: Total monthly household and fuel expenditure by income group for non-electrified metropolitan households
Source: SALDRU (1993)

From tables 2.11 to 2.13, it is evident that there is not a substantial variation in fuel expenditure between the different income groups except in the highest income category in electrified households, which can possibly be attributed to the acquisition of luxury electrical appliances among higher income electrified households. Among non-electrified households, there is minimal variation in fuel expenditure between the income groups. Fuel expenditure as a proportion of total household expenditure is, however, much greater among the lowest income group (10-12%) as compared with the highest income group (4%).

The average fuel expenditure is greater among electrified than non-electrified households. It is possible that this can be attributed to differences in levels of appliance ownership, efficiencies of fuels and the cost of the different fuels.

2.7.2 Energy expenditure by dwelling type[6]

Tables 2.14 to 2.16 show energy expenditure as a percentage of income for the different dwelling types and in the different metropolitan focus areas.

	Johannesburg	Port Elizabeth	Durban	Cape Town
Average income (R's)	945	828	1 119	1 277
Average expenditure on energy (R's)	74.4	56	81.8	85.75
% of income spent on energy	**7.9**	**6.8**	**7.3**	**6.7**

Table 2.14: Percentage of income spent on energy: all households
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg	Port Elizabeth	Durban	Cape Town
Average income (R's)	1458	996	1342	1 550
Average expenditure on energy (R's)	70.8	62	91.6	112
% of income spent on energy	**4.9**	**6.2**	**6.8**	**7.2**

Table 2.15: Percentage of income spent on energy: formal households
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

6 Figures for average energy expenditure in the Cape Town area are drawn from Thorne and Qangule (1994) which focused on electrified households only. The figures are, therefore, not representative of non-electrified households.

	Johannesburg		Port Elizabeth			Durban	Cape Town	
	PI	UI	PI	UI	B/Y	I	I	B/Y
Average income (R's)	829	782	688	570	595	914	914	923
Average expenditure on energy (R's)	81.2	70.4	50	39	41	73.3	85.5	60
% of income spent on energy	**9.8**	**9**	**7.3**	**6.8**	**6.9**	**8**	**9.4**	**6.5**

Table 2.16: Percentage of income spent on energy: planned and unplanned informal housing and backyard shacks
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

It is evident from tables 2.14 to 2.16 above that poorer informal households spend a larger proportion of their income on energy. The average amount spent on energy within each metropolitan area is relatively consistent between the different dwelling types. Variations do exist between the different metropolitan areas, however, with Port Elizabeth experiencing much lower levels of fuel expenditure. This may reflect the lower level of electrification and the higher level of poverty in the area.

1.8 Employment and levels of dependency

Figures for levels of unemployment and dependency vary substantially according to how these socio-economic indicators are defined. In the past, the official South African definition of unemployment referred to those people within the economically active[7] sector of the population who were actively seeking, but unable to find, work. More recently, in recognition of the socio-economic issues surrounding work seeking, the official definition has been expanded to include those people who have had the desire to work without taking any concrete steps to secure employment. The figures presented in table 2.17 below are the official estimates of unemployment for the urban black population of Gauteng, Kwazulu/Natal and the Eastern and Western Cape.

	1994 census data
Gauteng	37.2%
Eastern Cape	31.4%
Kwazulu/Natal	38.1%
Western Cape	25.1%

Table 2.17: Levels of unemployment among the urban black population in selected provinces of South Africa[8]
Source: Central Statistical Services (1994)

The figures presented in table 2.14 tend to underestimate the levels of unemployment as they do not take into account underemployment. Furthermore, these figures are not representative of the poor as they reflect the full range of income groups. Studies of unemployment among the urban poor show the levels of unemployment to be much higher than reflected in these figures. Cobbledick and Sharrat (1993) show the unemployment rate for the poor in the Durban Region to be 75.4%.[9] Unemployment is defined here to include those who are under-employed. Levin and Sofisa (1993) quote Riordan (1988) who found that 60% of all unemployed come from households living below the household subsistence level (HSL). They further quote the Human Rights Trust who found that in the shack area of Silvertown in Port Elizabeth, 90% of all

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7 The *economically active sector* of the population are those people aged between 16 and 64 (that is, the potential work force).

8 These unemployment figures are calculated using the expanded (or relaxed) definition of employment. In terms of the definition, a person need not have taken definite steps to obtain work or undertaken self-employment in order to be classified as unemployed, but simply have had the desire to work.

9 This figure is representative of the poor in the urban area of Durban, but may include peri-urban and rural communities within this region.

unemployed persons were from households living below the HSL. This demonstrates that levels of unemployment are much higher among the poorer sector of the population.

Table 2.18 below demonstrates the strong link between unemployment and poverty. It shows that the unemployment rate among the poorest 20% of the population is 53.4%, compared to 4.4% among the richest 20% of households. Africans have a much higher unemployment rate than all other races, at 38%. Women suffer from a 35% unemployment rate, compared to only 26% among men. Finally, in the metropolitan areas, 58.3% of the poorest 20% of the population are unemployed compared to only 4% of the richest 20% of the population.

	Households ranked by consumption groups of 20% (quintiles)					
	Quintile 1	*Quintile 2*	*Quintile 3*	*Quintile 4*	*Quintile 5*	*Total*
RACE						
African	54.3	44.2	32.0	19.7	13.1	38.3
Coloured	34.3	32.5	21.2	14.5	6.8	20.8
Indian	*	*	23.3	12.6	3.7	11.3
White	*	*	25.8	9.4	2.8	4.3
GENDER						
Female	56.7	46.2	37.2	23.3	5.8	35.1
Male	50.2	40.5	24.4	13.2	3.3	25.5
LOCATION						
Rural	53.7	44.3	30.6	13.2	5.9	39.7
Urban	49.9	38.5	30.3	16.1	4.2	25.6
Metropolitan	58.3	45.0	30.3	19.5	4.2	21.3
Total	**53.4**	**43.3**	**30.4**	**17.1**	**4.4**	**29.9**

Table 2.18: Unemployment rates by race, gender and location (%)
Source: SALDRU (1995)

SALDRU (1995) shows that in South Africa, as a whole, the dependency ratio is more than twice as high among the poor than the better-off (1.1 among the poor, as against 0.5 among the non-poor).

Two measures of dependency are identified and used in this paper. Firstly, dependency can be expressed as a ratio of those who are in the economically non-active section of the population to those who are economically active (refer to table 2.19). This ratio may be misleading in that the economically active sector may be unemployed and themselves dependent on others (Cobbledick & Sharratt 1993). An alternative ratio measures the number of those who do not have full-time employment to those who do, whether in formal or informal activities. This method may also be problematic in that it considers retired persons as dependent, when they may in fact be independent, receiving income from transfers (refer to table 2.21).

	% of non-economically active	*% of economically active*	*Dependency ratio*
Johannesburg	44	56	0.8
Port Elizabeth	57	43	1.3
Durban	52	48	1.1
Cape Town	50	50	1

Table 2.19: Dependency levels expressed as a ratio of the number of non-economically active to the number of economically active
Source: Central Statistical Services (1994)

The figures presented in table 2.19 above are for the magisterial districts corresponding with the consumption data. The figures include both rural and the urban population, but the rural population of these areas is very small, ranging from 3% in Cape Town and Port Elizabeth to 5% in the Durban region and 8% in Johannesburg. These figures do not, however, reflect the position of the poor as they include the full range of income groups. Table 2.20 below shows the dependency levels for the provincial black population, taking into account unemployment.

	% non-economically active and unemployed	% employed	Dependency ratio
Gauteng	56	44	1.27
Eastern Cape	60	40	1.5
Kwazulu/Natal	60	40	1.5
Western Cape	52	48	1.1

Table 2.20: Provincial dependency levels for the black population expressed as a ratio of the number of non-economically active and unemployed economically active to the number of employed in urban areas
Source: Central Statistical Services (1994)

	% of sample not in full-time employment	% of sample in full-time employment	Dependency ratio
Port Elizabeth[10]	82	18	4.6
Durban[11]	72.3	27.7	2.6

Table 2.21: Alternative dependency ratios for Port Elizabeth and Cape Town expressed as a ratio of the number of those who have full-time employment to the number of those who do not

Table 2.21 demonstrates dependency levels found among the urban poor in Port Elizabeth and Durban, taking into account unemployment and under-employment.

1.9 Qualitative considerations

1.9.1 Movements of people

It is difficult to quantify peoples' movements but important to take them into account. People surveyed in the studies utilised to compile this paper move between areas for various reasons which include among others, having family homes in the former homelands and in some instances having access to two homes; moving from unplanned to planned areas; moving from informal to formal housing or working away from family locations in the former homeland. Movements affect energy use patterns in a number of ways. Firstly, these movements result in fluctuations in household size and, therefore, have implications for levels of energy consumption. Secondly, they affect perceptions of permanence, which in turn affects appliance acquisition and fuels used. Finally, they potentially affect the viability of electricity as a source of energy. Where households pay a flat rate for electricity, they are faced with electricity bills even when they are away and are not using energy (James 1996). If the household opts for disconnection, they are charged to be reconnected. Disconnection is viable only if away for long periods of time and, therefore, the household bears the burden of paying for fuel in two locations.

1.9.2 Fuel sharing

Fuel-sharing between households influences the organisation of households and strengthens inter-household relationships (Mehlwana & Qase 1996: 36). This has various implications for fuel use patterns. The dearth of information on fuel sharing is acknowledged by Mehlwana and Qase (1996).

There is also some inconsistency among the various studies of the role of fuel sharing in the different metropolitan areas. White (1995) argues that the acceptability of fuel sharing varies between the major urban centres. She contends that in Durban, paraffin sharing is accepted as a way to get to know one's neighbours and is constantly circulating in small quantities, while in Gauteng and Cape Town, paraffin-borrowing is considered to be completely unacceptable.

10 The figures for Port Elizabeth are taken from the area of Ibhayi (adapted from Rossouw & van Wyk 1993).

11 The figures for Durban are taken from the areas of urban Umlazi and urban Ntuzuma (including Bambayi, Kwa Mashu and Inanda/Newtown) (adapted from Cobbledick & Sharrat 1993).

White (1995) states that the differences between these areas has been linked to the extension of credit to their customers by spazas. Where credit is readily available, as in Gauteng and Cape Town, paraffin-sharing is considered taboo. The spazas are always open and a resident can always collect paraffin even if he/she has no money. In Durban, where credit is less readily available, people choose to use paraffin because it lends itself to distribution in small quantities, enabling fuel sharing to take place and thus facilitating social relations (White 1995). In contradiction, Mehlwana and Qase (1996) emphasise the importance of fuel sharing and its implications in Cape Town, stressing the wider kin and friend networks and relationships used to channel fuel-related activities.

While it is acknowledged that the consideration of fuel sharing is important in formulating a least cost energy plan, contradictions in existing studies need to be overcome with more reliable research. It raises the need for qualitative research to be conducted on an ongoing basis.

Chapter 3
THERMAL EFFICIENCY OF HOUSING

3.1 Introduction

Buildings provide shelter, modifying the naturally occurring climate in order to achieve an acceptable level of indoor comfort[1] (Hawkes et al 1995). The degree of change is influenced by two main factors:

- the design and layout of the building, and
- the materials used in construction.

The way in which these factors work together to create a modified indoor environment, is called the thermal performance of the building (Meyer 1983).

In many parts of South Africa, high levels of thermal discomfort are experienced in the summer months when overheating occurs inside houses. Thermal improvements can substantially modify summer indoor temperatures, creating more liveable environments. As no active cooling is performed in low-income housing, the benefits of thermal improvements on summer cooling are difficult to quantify. Most studies determining the effects of thermal improvements in low-cost housing, therefore, tend to focus on the energy savings that can be made by reducing the heating burden in the winter season, neglecting the summer benefits of these improvements. As this paper is concerned with energy consumption patterns, the focus of this chapter will also be on the winter space heating burden.

The internal environment of a building is influenced by three potential sources of energy: the ambient energy of the external climate, the metabolic energy of the activities and processes which the building accommodates and generated energy which primarily comes from non-renewable sources of fossil fuel (Hawkes et al 1995). The poorer the thermal performance of a building, the more fuel is required to maintain an acceptable level of comfort. By improving the thermal performance of a building, one can minimise the need for generated energy for winter heating and thus reduce household fuel costs.

3.1.1 Energy savings through thermal improvement

Recent studies by Holm et al (1994 cited in Olivier 1995), Van Wyk and Mathews (1995) and Mathews et al (1995) have found that substantial energy savings can be made in both the formal and the informal housing sectors through the installation of simple measures of thermal efficiency.

Holm et al (1994) estimated that savings of up to 85% of the domestic heating bill could be achieved through the installation of ceilings and insulation. Van Wyk and Mathews (1995) estimated that savings of between 60 and 74%[2] of the household heating bill could be achieved through the installation of ceilings, while savings of approximately 90% of total energy consumed for heating could be achieved through the installation of insulated ceilings in formal houses. Figures 3.1 and 3.2 demonstrate the annual heating requirements of a standard low-cost formal house[3] and the energy savings that can be made through the installation of ceilings and insulation respectively in formal housing.

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1 Acceptable indoor thermal environmental conditions have been set by Wentzel (1982) as between 16oC and 32.5oC. It has been found that when room temperatures fall below 16oC to 18oC, most people will employ sources of generated energy to heat the space.

2 The 60% refers to the savings which can be achieved by installing makeshift cardboard ceilings in informal dwellings, while the 74% refers to savings which can be achieved through the installation of commercial ceilings in formal houses.

3 The standard formal house investigated was a $54m^2$ house, constructed of clay bricks and a corrugated iron roof.

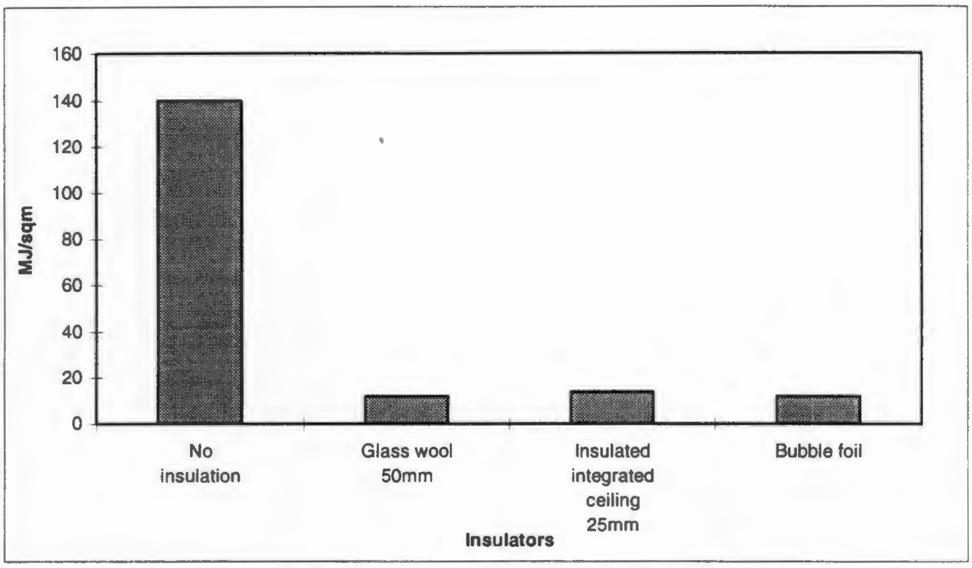

Figure 3.1: Annual heating requirements
Source: Van Wyk & Mathews (1995a)

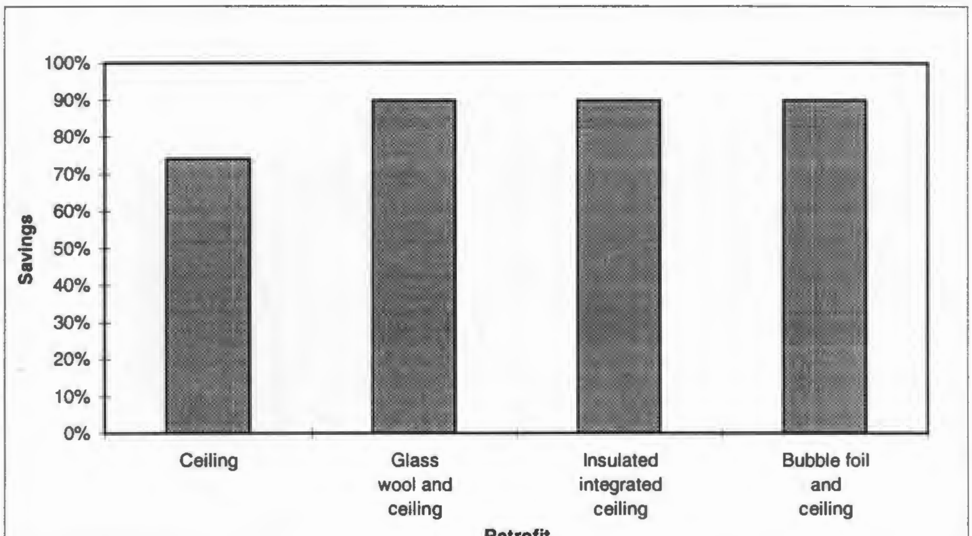

Figure 3.2: Savings through retrofit
Source: Van Wyk & Mathews (1995a)

The quantities represented in figures 3.1 and 3.2 are estimates for the Gauteng area. The amounts of energy consumed and the levels of energy that can be saved through thermal improvements are climate dependent and will vary from area to area. Furthermore, these figures assume that households will want to maintain a minimum indoor temperature of 16°C. If households maintain temperatures higher than 16°C, the potential savings achieved through the installation of insulation and ceilings will be reduced.

3.1.2 Climate and thermal performance

In chapter one, it was pointed out that climatic conditions vary both geographically across South Africa and seasonally within regions. These variations in climatic conditions impact significantly on household energy use patterns, particularly the need for space heating. Table 3.1 compares the average monthly delivered energy consumption in four regions of South Africa, showing that the total energy consumption of households in the colder area of Gauteng is considerably higher than in the temperate areas of Port Elizabeth and Cape Town and the subtropical area of Durban. While these variations in total household consumption of delivered energy do reflect differences in heating requirements between the geographical areas, some of the variation can be attributed to differences in the types and costs of fuels used and differences in the efficiencies of appliance/fuel combinations (Eberhard & Van Horen 1995).

	Formal electrified	Formal non-electrified	Planned informal	Unplanned informal
Gauteng	3 358	5 457	5 668	4 199
Durban and Pietermaritzburg	1 935	3 156	2 665	2 069
Cape Town	1 942	1 561	1 461	1 392
Port Elizabeth and East London	1 252	1 098	1 007	1 013

Table 3.1: Average monthly household energy consumption (in delivered MJ)
Source: EPRET 1993 cited in Eberhard & Van Horen (1995)

The variability of climate also has implications for construction and design. The amount of fuel required for heating purposes can be tempered by using appropriate construction materials and design strategies in residential buildings. Information on the means and fluctuations in climate can be used to determine whether or when a building requires heating and/or cooling to maintain an acceptable level of comfort. In this way, climatic data, specifically the parameter of temperature, together with solar geometry, can be used to select appropriate design strategies and construction materials for building in a specific area.

Figure 3.3 details the climatic conditions and bio-climatic requirements during the seasonal and diurnal cycles for hot humid (Durban), moderate temperate (Cape Town, Port Elizabeth and Gauteng) and dry climatic zones. In these cases, the range which is desirable for comfort (that is, the comfort zone) falls between 21°C and 26°C and between 30% and 65% relative humidity. The diagram also shows how comfort can be established outside the comfort zone through increasing the moisture content of the air (A), increasing air movement (B), applying radiant heat (C) and increasing the number of layers of clothes (CLO factors) (Thorne 1995).

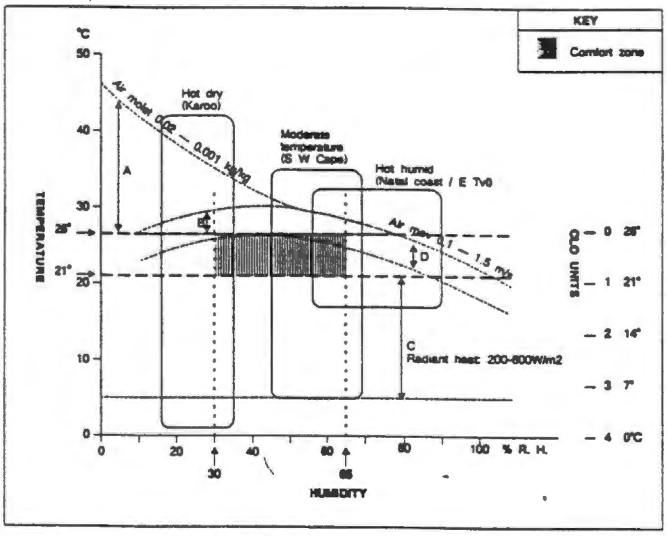

Figure 3.3: Bio-climatic diagram
Source: Thorne (1995)

3.2 Attitudes toward and perceptions of thermally efficient housing

It is a common perception that affordability is the sole factor prohibiting low-income households from making thermal improvements to their houses. While affordability remains a dominant reason, particularly with regard to commercial insulation, there are other attitudinal, perceptual and practical reasons why households do not consider the installation of insulation and ceilings.

Much work has been done on the use of cardboard and other inexpensive materials to improve the thermal efficiency of low-income households[4]. While there is validity in the statement that these materials can substantially improve the thermal performance of informal dwellings and

[4] Mathews et al (1995), Van Wyk & Mathews (1995a) and Van Wyk & Mathews (1995b).

low-income households do already use these materials themselves, many households are opposed to using such materials for a variety of reasons.

White (1995a, 1995b) investigates the reasons why households do not install ceilings in houses. The reasons include:

- affordability (that is, the first cost or capital cost of installing a ceiling);
- ignorance (almost half the respondents in all settlement types in the Gauteng study believed that one would install a ceiling only for decorative purposes and, therefore, ceilings do not enjoy a high priority in low-income housing);
- aesthetics (in the Gauteng study, it was found that in 'formal houses, the owners are not prepared to install informal or makeshift ceilings, even when they know this would improve thermal efficiency. They prefer the appearance of bare zinc to the "mess" of something less formal' (White 1995a: 38);
- shacks leak and therefore new roofing is a priority over ceilings;
- safety precautions (the use of paper and other lightweight materials to insulate shacks is considered a fire hazard in households using candles and paraffin as primary fuels);
- lack of security of tenure (shacks are not perceived as being permanent homes and thus owners are not willing to embark on the effort and expenditure); and
- practical problems relating to the difficulty associated with installing ceilings in shacks where there are no crossbeams to support the ceiling.

3.3 Thermal efficiency

While design and layout are important factors influencing the thermal performance of a building, the remainder of this chapter focuses on the types and relative efficiencies of construction materials used in low-cost houses in the selected metropolitan areas.

There are several factors which need to be taken into consideration when selecting construction materials for housing. These include the local climatic conditions, desirable levels of comfort, and the efficiency of the building materials. The following section focuses on the latter variable.

Heat flows through a material from the warmest to the coolest surface. An external surface heated by the sun will cause a heat flow to the interior. Similarly, an external surface exposed to the cold night sky will cause an outward heat flow from the warm interior. The materials used in the construction of roofs, floors and walls influence the way in which heat flows between the interior and the exterior of a building.

Each layer of the building construction will conduct a certain amount of heat depending on its density. Materials with low mass have a low conductivity and high resistance to heat flow and serve to insulate the building. Materials with high mass have a high conductivity and low heat resistance.

3.3.1 Measurements of thermal performance

A variety of measurements are used to evaluate the efficiency of building elements. Two of these measurements, the thermal conductivity (k-value) and the thermal transmittance (U-value) of the materials are discussed below.

3.3.1.1 Thermal conductivity (k-value)

The thermal conductivity (k) of a material is defined as the rate at which heat is conducted through the material under specified conditions. The k-value is measured as the heat flow in watts across a thickness of 1 metre for a temperature difference of 1°C and a surface area of $1m^2$ (McMullan 1983). The conductivity of materials varies with their thickness. Materials such as aluminium, copper and steel have a high conductivity, while materials such as concrete and brick have lower conductivity than the metals but will still conduct considerable heat. Materials that have a low conductivity are considered insulators (for example, mineral wool, asbestos, glass fibre, cork etc).

3.3.1.2 Thermal transmittance (U-value)

In many instances, building elements (such as walls, roofs and floors) are made up of air spaces and a variety of materials. Different materials conduct heat at different rates and, therefore, in these cases, heat is transferred through the element of building by a number of mechanisms (McMullan 1983). A U-value is a single measurement describing the behaviour of the *complete structural element* (made up of a range of component materials) and can be described as the overall rate at which heat is transmitted through a particular thickness of roof, wall or floor (McMullan 1983). The U-value is measured as the rate of heat flow in watts through 1m^2 of a structure when there is a temperature difference across the structure of 1°C. The lower the U-value, the better the insulation. For example, a wall with a U-value of 0.5W/m^2 °C loses heat at half the rate of a wall with a U-value of 1.0 W/m^2°C. The cost of replacing heat lost through the first wall will thus be half that of the second wall (McMullan 1983).

3.3.2 Efficiencies of different construction materials

A comparison of the thermal conductivity of some the materials used in low-income housing is presented below.

Materials	*Density (kg/m^3)*	*Conductivity (k-value) (W/m°C)*	*Specific heat capacity[5] (kJ/kg°C)*
Bricks	1 200	0.31	*
	1 600	0.54	*
	1 922	0.727	0.840
	2 000	0.92	*
Wood			
Softwood	500	0.14	*
Hardwood	650	0.16	*
Pine	660	0.15	1.400
Concrete	1 000	0.30	*
	1 400	0.51	*
	1 800	0.87	*
	1 986	1.5	0.880
	2 400	1.83	*
Concrete slabs	2 300	0.930	0.650
Zinc/iron	7 100	118.00	*
Asbestos cement			
Pressed	2 100	0.620	0.830
Unpressed	1 830	0.480	0.840
Tiles			
Clay	1 300	0.83	*
	1 922	0.840	0.920
Asphalt	243	1.230-	1.460
Sheet materials			
Plywood	530	0.140	1.400
Plasterboard	993	0.170	1.050
Chipboard	700	0.110	*
Hardboard	1 121	0.200	1.360
Plaster			
Dense	1 422	0.480	0.880
Lightweight	600	0.170	*

Table 3.2: Thermal properties of different construction materials
Source: Burberry (1983); QUICK

Table 3.2 above demonstrates the much higher conductivities that are found in metals, such as zinc/iron than in all other materials. The implications of this are that zinc/iron is far more responsive to ambient temperature and has little effect in moderating the indoor temperature.

[5] The specific heat capacity (c) of a material is the quantity of heat energy required to raise the temperature of 1 kg of that material by 1°C (McMullan 1983).

The reason for this is that heat is transferred rapidly between the interior and exterior. This means that it is difficult to keep heat both in out of the dwelling structure.

The low thermal performance of zinc/iron is further demonstrated by the following two practical examples. Firstly, Mathews et al (1995) investigated the performance of the following three types of building materials - adobe and thatch, corrugated iron and wood and corrugated iron. They found that the adobe walls and thatch roof provided the best thermal performance and that corrugated iron structures performed the most poorly. Secondly, Van Wyk and Mathews (1995a) calculated that a corrugated iron structure in Gauteng uses $1300MJ/m^2$ per heating season to achieve the minimum acceptable indoor air temperature of 16°C. This compares very unfavourably with the $400MJ/m^2$ needed to heat an ordinary brick building and the $150MJ/m^2$ needed to heat an improved brick building.

It is important to note that different materials with different thermal qualities are more or less appropriate in different climatic zones. For example, heavyweight materials of construction[6] can be used to dampen the effects of large diurnal variations in outdoor temperature and solar radiation in areas under transient heat flow conditions, such as hot, arid regions (Meyer 1983). However, in climates where the daily outdoor temperature variations are small but solar radiation intensities are high, such as warm humid climates, heavyweight constructions can be a distinct disadvantage. The reason for this is that such structures cannot cool down sufficiently during the night to allow reasonably comfortable sleeping or working conditions. Under these circumstances, lightweight structures[7] that are adequately insulated can be thermally more desirable (Meyer 1983).

3.4 Materials typically used in the construction of houses

The materials used in the construction of houses varies from area to area and between dwelling types. The type of materials used is determined primarily by cost and availability. The following section draws a comparison between materials used in the construction of walls and roofs in the selected urban areas of South Africa and between the different dwelling types.

3.4.1 Gauteng[8]

Most of the formal houses in the Gauteng area are constructed of bricks and/or blocks (95%), while most of the informal houses (both planned (89%) and unplanned (85%)) are constructed of iron. Other materials used to construct walls are concrete and wood (see figure 3.4).

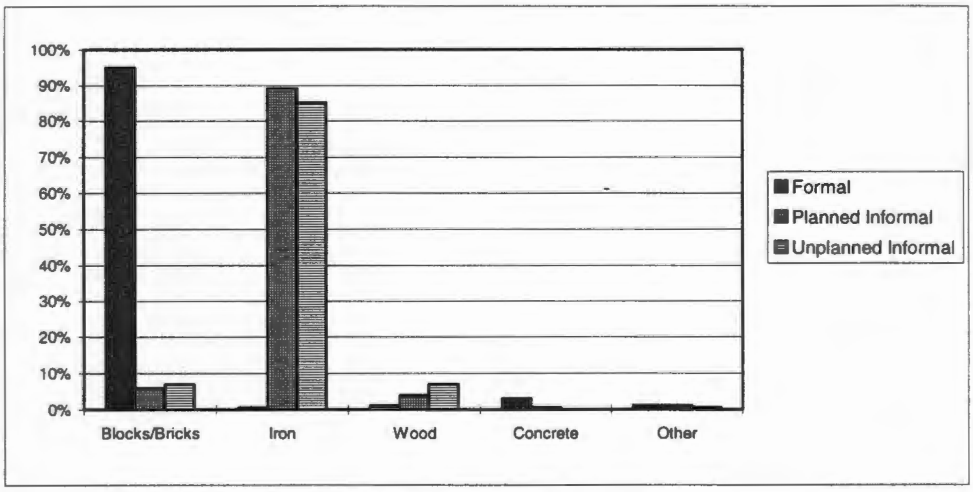

Figure 3.4: Materials used to construct walls: Gauteng

6 Materials with a high thermal mass or heat storing capacity.

7 Lightweight structures are those where the walls have a mass of less than $122kg/m^2$ (Meyer 1983).

8 The information for the Gauteng area is drawn from two sources - Hoets and Golding (1992) and White (1995).

Roofing of formal houses is constructed out of three main materials - iron (41%), asbestos (27%) and tiles (24%). The predominant material used for roofing of informal housing is iron (see figure 3.5).

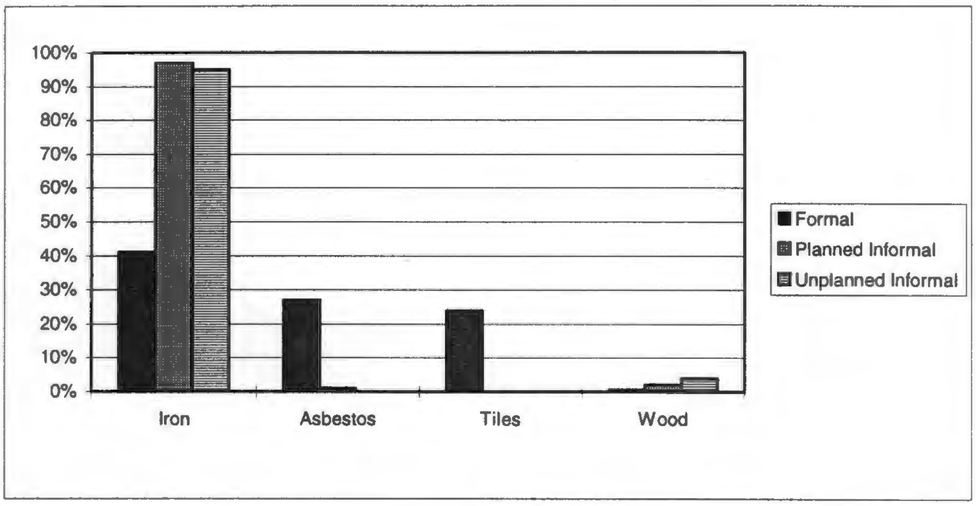

Figure 3.5: Materials used to construct roofs: Gauteng

Less than half (49%) of the formal low-income houses in Gauteng had ceilings, while the proportion of informal houses with ceilings is very small (less than 5%) (refer to figure 3.6). Informal dwellings may use a variety of materials as wall coverings, some of which serve as insulation. Such materials include large advertisements printed on paper, posters and wall paper. Cardboard, masonite boards, chipboard and plywood panels are also used to insulate shacks.

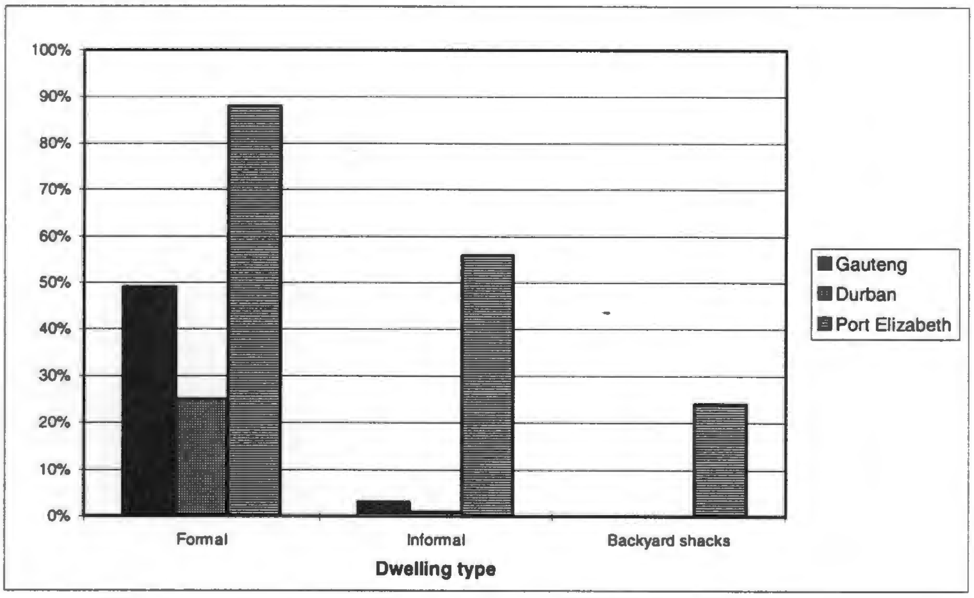

Figure 3.6: Proportion of dwellings with ceilings

3.4.2 Cape Town[9]

All the formal houses sampled in Cape Town were constructed of bricks. Planned informal houses are constructed primarily of zinc, while unplanned informal houses and backyard shacks are constructed predominantly of timber (47% and 33% respectively) and/or zinc (20% and 47% respectively) (refer to figure 3.7).

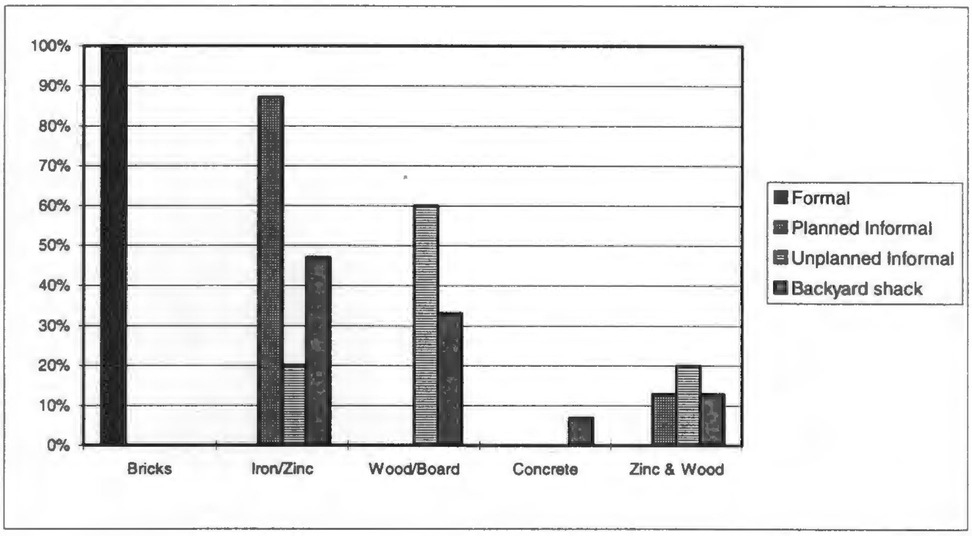

Figure 3.7: Materials used to construct walls: Cape Town

In the Cape Town sample, asbestos was used exclusively for the roofing of formal housing. In the construction of planned informal housing, zinc was the most commonly used roofing material, while in the construction of unplanned informal dwellings and backyard shacks, wood, zinc and plastic sheeting were the most commonly used roofing materials (refer to figure 3.8).

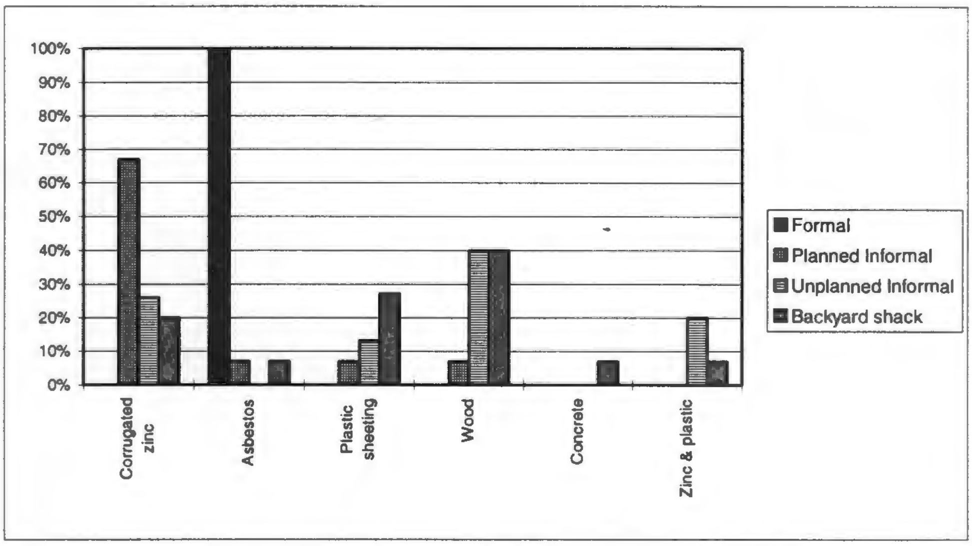

Figure 3.8: Materials used to construct roofs: Cape Town

9 The information for Cape Town is drawn from Mehlwana and Qase (1995).

3.4.3 Port Elizabeth[10]

Formal houses in Port Elizabeth are constructed predominantly out of cement (67%) and bricks (25%). Planned informal houses and backyard shacks are constructed out of zinc (81% and 88% respectively) and to a lesser degree wood (17% and 12% respectively), while unplanned informal houses are constructed entirely out of zinc (see figure 3.9).

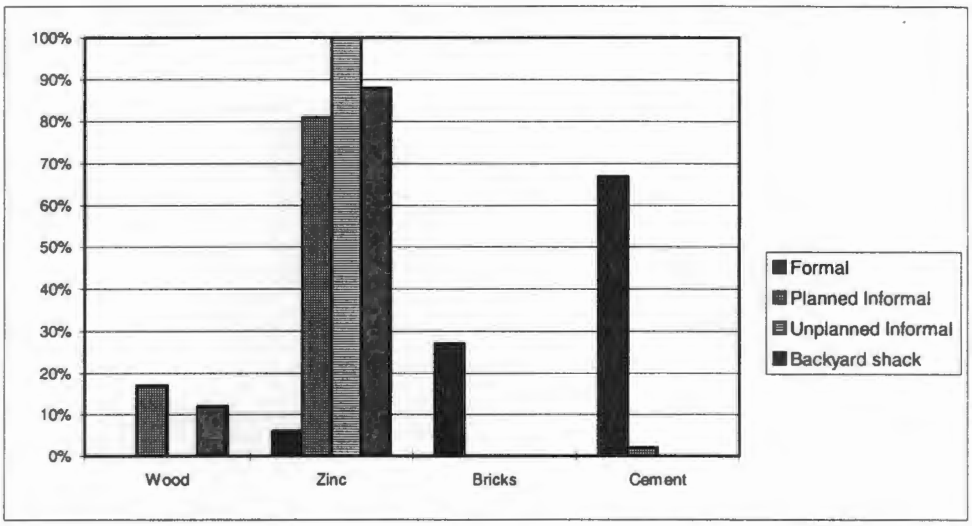

Figure 3.9: Materials used to construct walls: Port Elizabeth

As in the case of Cape Town, the predominant roofing material of formal housing in Port Elizabeth is asbestos. Roofing of unplanned informal dwellings is constructed of asbestos (54%) or zinc (46%), while zinc is used almost exclusively as a roofing material in planned informal and backyard shack dwellings (refer to figure 3.10).

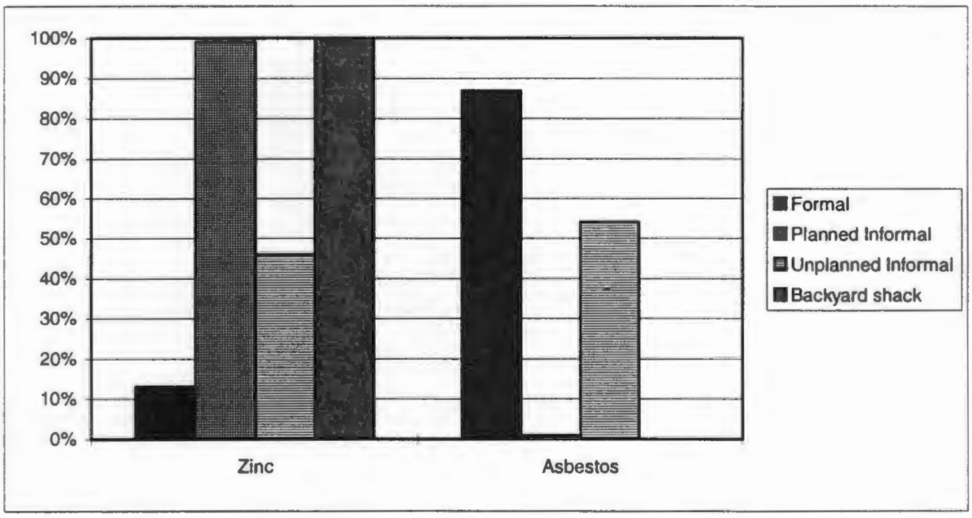

Figure 3.10: Materials used to construct roofs: Port Elizabeth

A much higher proportion of dwellings are fitted with ceilings in Port Elizabeth than in the other metropolitan areas. Close to 90% of the formal houses and approximately half the informal houses (both planned and unplanned) are fitted with ceilings (refer to figure 3.6).

10 The information for Port Elizabeth is extracted from the Rossouw and Van Wyk (1993) study.

3.4.4 Durban[11]

Most of the formal houses in the Durban Region are constructed of bricks and/or blocks (98%). In contrast to the other metropolitan areas studied, most of the informal dwellings in the Durban Region are constructed of wattle and daub (69%). Other materials used in the construction of walls of informal dwellings are blocks (18%) and to a lesser extent wood/board (6%) (see figure 3.11).

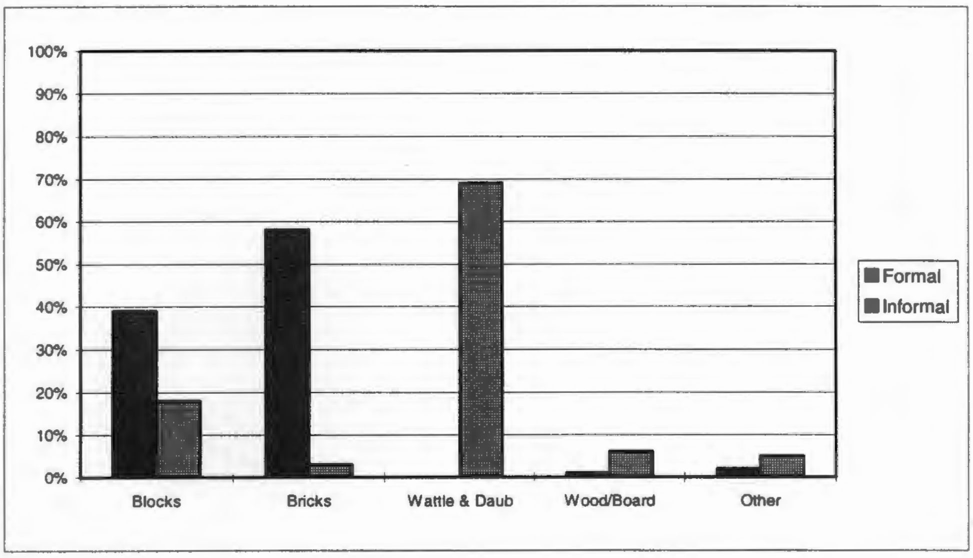

Figure 3.11: Materials used to construct walls: Durban

The predominant material used in the roofing of formal houses is asbestos (81%). Tiles (15%) are used to a lesser extent. The predominant materials used in the roofing of informal houses are iron (59%) and asbestos (37%) (see figure 3.12).

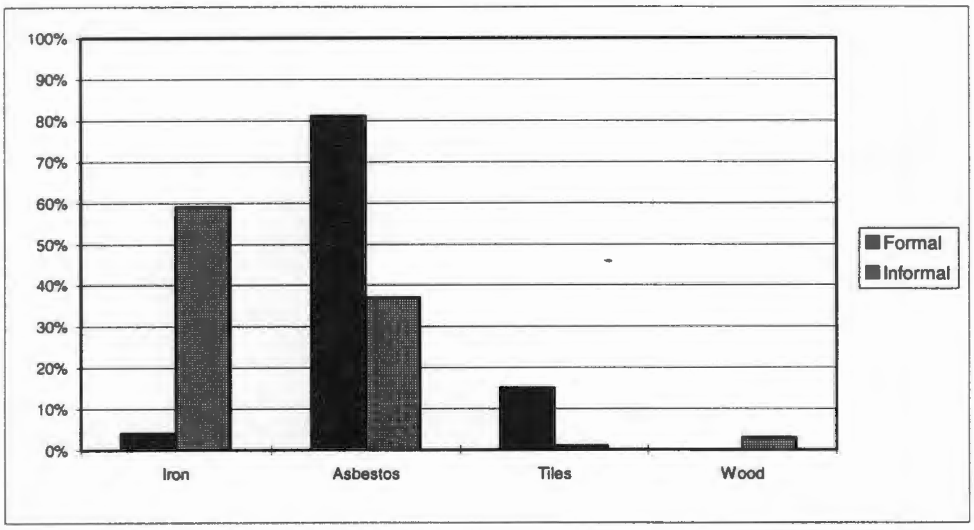

Figure 3.12: Materials used to construct roofs: Durban

A quarter (25%) of the formal houses in the Durban Region are fitted with ceilings, while the proportion of informal houses with ceilings is almost negligible (1%) (see figure 3.6).

[11] The information for Durban is drawn from the Hoets and Golding (1992) study.

3.4.5 Conclusion

Based on the above description of construction materials used in low-income housing, it can be concluded that low-income dwellings exhibit low levels of thermal performance.

There is relatively little variation in the construction materials used in formal housing. Walls are constructed predominantly of bricks or cement, while roofs are constructed of asbestos and to a lesser degree, iron and tiles. While bricks and cement are not in themselves poor insulating materials, the thickness and quality of the materials is sacrificed in low-income housing and, consequently, the walls have higher conductivities than normal. Iron/zinc, a common roofing material in the Gauteng province, has a very high conductivity and is a poor insulating material.

The three main materials used in the construction of informal housing are iron/zinc, wood and wattle and daub. While wattle and daub has fairly good thermal performance qualities, iron/zinc has a very high conductivity (118W/m°C) and a poor thermal performance. Furthermore, these informal structures are difficult to insulate due to inadequate weatherproofing and their physical structure.

Olivier (1995: 3) states that 'most low-cost houses, in an effort to keep them low in cost, are constructed without ceilings and almost never with an insulated ceiling'. He further argues that 'the provision of a ceiling, and particularly an insulated ceiling, will result in a considerable improvement in the indoor temperature range of the house with the concomitant reduction in need for space heating'.

In Gauteng and Durban, the proportion of low-income houses, particularly informal dwellings, fitted with ceilings is small. The situation in Port Elizabeth is markedly different with most of the formal houses and approximately half of the informal dwellings (both planned and unplanned) being fitted with ceilings. No data was available for Cape Town on the proportion of dwellings with ceilings.

It is clear that there is considerable room for improvement in the thermal performance of low-income formal and informal dwellings. Different strategies need to be targeted at the different dwelling types. For new buildings in the formal housing sector, energy efficient building codes, quality control and innovative delivery systems may alone be appropriate strategies, while for the existing housing stock, novel retrofit methods and measures need to be explored.

Addressing thermal performance improvements in informal housing is a more complicated issue. There is a need for practicable, low cost methods of improving the thermal performance of informal housing. Researchers have turned to the use of cardboard as an insulating material in informal housing and low-income formal housing. While the use of cardboard as a means of reducing wind and dust infiltration is a common practice in informal dwellings, there are some practical problems associated with its use. These have been identified by White (1996) and Mehlwana and Qase (1996) and include:

- safety risks (the use of paper and other lightweight materials to insulate shacks is considered a fire hazard in households using candles and paraffin as primary fuels); and
- practical problems such as the difficulty of installing ceilings in shacks where there are no crossbeams to support the ceiling.

Many households which do line their shacks with cardboard, leave the cooking area clear of cardboard in order to reduce the threat of fire. Thus the area of the shack which is generally the source of heat is uninsulated and much heat is likely to be lost through the shack walls.

Further issues have been raised around how that cardboard is used. Cardboard placed flat against iron walls provides minimal insulation, whereas fluted cardboard creating air spaces between the iron walling and the interior of the shack, provides much better insulation. In moist areas of South Africa, such as Cape Town, flooring is an important thermal consideration. While some shacks in the Cape Town area were found to have raised timber floors reducing the infiltration of water into the dwelling structure, other shacks had bare floors which when flooded were uninhabitable. Although raised floors may be considered a luxury, it is clear that they have an important role to play in improving the thermal performance of the dwelling structure. There is a need, therefore, to inform informal households how best to insulate, orientate and construct their shacks in an affordable manner. To this end, research and development of appropriate materials is required.

Chapter 4
ACCESS TO SERVICES

4.1 Introduction

The level of access to services, such as electricity and water, has important implications for patterns of energy consumption. The following section presents the levels of access to these services and analyses the implications of quality of access for end-use consumption patterns.

4.2 Access to electricity

A national household grid electrification programme commenced in the early 1990s. However, the programme only began in earnest when, in 1993 and 1994, the National Electrification Forum (NELF)[1] set electrification targets for the distribution industry. In 1994, the target was 350 000 new connections. The annual target was increased to 450 000 in 1996 and will remain constant until the year 1999, after which it starts to decline. These targets are expected to lead to an increase in access to electricity from 44% of all households in 1994 to 65% in the year 2000 (Thom et al 1995). Since the conception of the national electrification programme, 1 515 847 new connections have been made (NER 1995).

Table 4.1 below shows the levels of electrification in the urban areas of the nine provinces of South Africa as of 31/12/1995. The highest levels of electrification are found in the Western Cape, Kwazulu/Natal and Gauteng. The lowest levels of electrification are found in Mpumalanga, Free State and the Eastern Cape. This information reflects all urban areas and all income groups.

	No of houses (urban)	*No of houses electrified (urban)*	*Percentage electrified (urban)*
Eastern Cape	495 315	333 053	67
Free State	357 266	241 532	67
Gauteng	1 682 288	1 307 335	78
Kwazulu/Natal	808 552	636 551	79
Mpumalanga	195 637	116 253	59
North West	229 120	160 053	70
Northern Cape	118 977	90 516	76
Northern Province	118 799	84 596	71
Western Cape	797 227	702 351	88
National urban total	**4 803 181**	**3 672 240**	**76**

Table 4.1: Levels of electrification in the urban areas of the different provinces as of 31/12/1995
Source: NER (1995)

Information on levels of electrification is also provided for the four main metropolitan areas. Table 4.2 reflects the provincial variations in levels of access to electricity, showing that electrification levels are lowest in Port Elizabeth and highest in Cape Town and Durban. However, much lower levels of electrification are experienced in Port Elizabeth than in the urban areas of the Eastern Cape as a whole.

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1 NELF was disbanded in 1995. It made several recommendations to the government before it was disbanded, one of which was to set up the National Electricity Regulator (NER).

	Houses	Access to electricity
Johannesburg[2]	1 673 000	71%
Cape Town[3]	587 000	81%
Durban[4]	398 000	80%
Port Elizabeth[5]	211 000	55%

Table 4.2: Levels of electrification in the metropolitan areas of Johannesburg, Cape Town, Durban and Port Elizabeth
Source: Davis (1995)

The information presented in tables 4.1 and 4.2 is not broken down into housing type and includes all income groups and thus does not reflect the position of the poor. Table 4.3 gives an indication of the levels of urban electrification per dwelling type for South Africa. These statistics show that there is a relatively high level of electrification among formal housing (which includes all income groups), but that electrification levels are very low amongst informal dwellings and backyard shacks (Davis 1995).

Housing type	*Houses*	*Electrified*	*Not electrified*	*% electrified*
Formal	3 500 000	2 700 000	800 000	77
Informal	714 000	224 000	490 000	31
Backyard shack	147 000	36 000	111 000	25
Total	**4 361 000**	**2 960 000**	**1 401 000**	**68**

Table 4.3: Access to electricity by dwelling type in the urban areas of South Africa
(figures are rounded to the nearest 1 000)
Source: Davis (1995)

Apart from the variations in levels of access between the different dwelling types, for those who do have access to electricity, the quality and cost of access varies. Backyard dwellings are not fitted with separate electricity meters and, therefore, households living in backyard shacks are dependent on the goodwill of their landlords for access to electricity (White 1996, Mehlwana & Qase 1996). The supply of electricity to backyard shacks is limited for three reasons: firstly, the electrical supply to backyard dwellings overloads the switchboards of the formal houses and places limits on how many appliances can be used simultaneously. Tenants thus have to limit their electricity use in order to prevent the power from tripping out. Secondly, because landlords are unable to meter the amount of electricity used by their backyard tenants, they charge an effective flat rate for electricity use. Landlords, therefore, have a strong incentive to either limit the supply of electricity to their tenants or to raise their rent. Thirdly, backyard tenants are prevented from using electricity if their landlord's electricity supply is cut off.

Furthermore, in settlements where electricity is supplied through the readyboard system, electrical usage is limited by structural arrangements. The placement of the readyboard is important in this regard. The readyboard is generally placed in a location which minimises the length of the connection wiring and, therefore, the placement is often inappropriate. For example, readyboards are often situated in the living room or bedroom, rather than in the kitchen. Electricity is thus used for media services and lighting in that room only, while households continue to use other fuels to meet all other needs.

2 Including all magisterial districts in the Gauteng province.

3 Including the magisterial districts of Bellville, Cape, Goodwood, Mitchells Plain, Paarl, Stellenbosch, Strand, Somerset West and Wynberg.

4 Including the magisterial districts of Durban, Chatsworth, Umlazi, Pine Town, Inanda and Vulamehlo.

5 Including the magisterial districts of Port Elizabeth and Uitenhage.

The following data extracted from the NELF data-base shows the levels of electrification in low-income households in the four main metropolitan areas of South Africa, corresponding with the areas[6] surveyed in the relevant energy consumption studies.

	No. of households	*No. electrified*	*% electrified*
Formal[7]	14 527	6 446	46
Planned informal[8]	63 284	31 492	50
Unplanned informal[9]	14 339	3 714	26

Table 4.4: Access to electricity in low-income households in Alexandra, Orange Farm and Zonkesizwe in Johannesburg
Source: NELF data-base (1995)

	No. of houses	*No. electrified*	*% electrified*
Formal houses	29 571	2 448	8.28
Planned informal	8 323	388	4.66
Unplanned informal	17 215	752	4.37
Backyard shack	3 017	132	4.37

Table 4.5: Access to electricity in low-income households in Ibahyi in Port Elizabeth
Source: NELF data-base (1995)

	No. of houses[10]	*No. electrified[11]*	*% electrified*
Formal houses	53 306	32 926	62
Planned informal	50 909	14 320	28

Table 4.6:[12] Access to electricity in low-income households in Umlazi, Kwa Mashu and Inanda/Newtown in Durban
Source: NELF data-base (1995)

	No. of houses	*No. electrified*	*% electrified*
Formal houses	7 057	6 634	94
Planned informal	3 763	1 355	36
Unplanned informal	24 370	10 479	43
Backyard shack[13]	7 381	1 550	21

Table 4.7: Access to electricity in low-income households in Langa and Khayelitsha in Cape Town
Source: NELF data-base (1995)

6 The areas of Zonkesizwe, Alexandra and Orange Farm in Johannesburg, Ibahyi in Port Elizabeth, Umlazi, Kwa Mashu and Inanda/Newtown in Durban and Langa and Khayelitsha in Cape Town are taken to be representative of low-income households in these areas.

7 The levels of electrification for formal housing is taken from the Alexandra township.

8 The levels of electrification for planned informal dwellings is a combined figure for Alexandra, Orange Farm and Zonkisizwe. The levels of electrification for planned informal housing varies substantially between the different areas, ranging from 26% in Alexandra to 56% in Zonkesizwe and 95% in Orange Farm.

9 The levels of electrification for unplanned informal dwellings is taken from Alexandra township.

10 The number of houses is a projected figure for 1995 based on growth rates.

11 The number electrified is a 1994 figure.

12 The figures presented in table 4.6 are averages for the areas of Umlazi, Kwamashu and Newtown. The levels of electrification vary substantially between the areas. For formal housing, levels of electrification range between 47% in Kwamashu and 71% in Umlazi. For informal housing, levels of electrification range between 7% in Newtown and 39% in Umlazi.

13 These figures are drawn from Mazur & Qangule (1995).

Tables 4.4 to 4.7 show that the areas sampled do reflect the established trends in variations of levels of electrification between provinces, metropolitan areas and dwelling types. Levels of electrification among low-income formal households in Gauteng, Port Elizabeth and Cape Town vary substantially from the national average presented in table 4.3. While the variations can be attributed, in part, to provincial variations and the focus on low-income households (as opposed to all households as in table 4.3), the socio-economic conditions (such as income and length of time established) of the areas selected also influence the levels of electrification.

4.3 Access to water[14]

Apart from the significance of adequate potable water with regard to issues of health and economic development, the level of access to adequate water supply is significant for present and future energy consumption patterns in terms of methods of water heating. Access to piped water is particularly relevant in terms of the potential for future use of geysers.

Table 4.8 gives an indication of the levels of access to various levels of water supply in the major metropolitan areas of South Africa. These figures are representative of the metropolitan areas, but cut across income groups and dwelling types.

	Gauteng	*Port Elizabeth*	*Durban*	*Cape Town*
Total urban population	8 744 000	967 000	3 086 000	2 560 000
House tap	63	53	66	72
Yard tap	11	18	0	12
Street tap - adequate	11	8	28	5
Street tap - rudimentary	6	0	0	0
Other - inadequate	9	21	5	11

Table 4.8: Levels of access to water supply expressed as a % in the four main metropolitan areas of South Africa
Source: Palmer Development Group (1993)[15]

Tables 4.9 to 4.11 show the levels of access to piped water within the poorer households of the four main metropolitan areas of South Africa. When comparing tables 4.7 and 4.8, it is clear that access to piped water is substantially lower among poorer households.

[14] Unless indicated otherwise, the figures for Johannesburg and Durban are taken from the Hoets and Golding (1992) study and the figures for Port Elizabeth are taken from Rossouw and van Wyk (1993). While access to water services is likely to have increased in the last three to four years, it is expected that the difference will not be great.

[15] Water supplies were considered adequate when there was planned provision of water (including house connections, yard taps or communal standpipes), at least one standpipe per 25 households, or communal standpipe within 50 metres. The level of water supply was considered inadequate when communal standpipes were provided on an ad hoc basis, there were more than 25 households per standpipe or standpipes were further than 50 metres from the household. Rudimentary water supplies were those where the quantity of water supplied was inadequate or where the quality of water was unacceptable (Emmet & Rakgoadi 1993).

	Johannesburg	Port Elizabeth	Durban	Cape Town
House tap	8	32	32	55
Yard tap	17	12	16	24
Street tap	53	53	48	-
Other[16]	21	3	4	21

Table 4.9: Level of access to water for all households in the metropolitan areas of Johannesburg, Port Elizabeth, Durban and Cape Town
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg	Port Elizabeth	Durban	Cape Town
House tap	36	65	67	91
Yard tap	33	24	32	8
Street tap	29	6	1	-
Other	3	5	0	1

Table 4.10: Level of access to water for formal households in the metropolitan areas of Johannesburg, Port Elizabeth, Durban and Cape Town
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

	Johannesburg		Port Elizabeth			Durban	Cape Town	
	PI	UI	PI	UI	B/Y	I	I	B/Y
House tap	0	0	1	0	0	0	7	21
Yard tap	17	10	0.5	0	0	2	47	31
Street tap	83	40	98	100	100	91	-	-
Other	0	50	0.5	0	0	7	46	49

Table 4.11: Level of access to water for informal households in the metropolitan areas of Johannesburg, Port Elizabeth, Durban and Cape Town
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mazur & Qangule (1995)

While access to piped water within the house is relatively high in low-income formal housing, with the exception of the Cape Town metropolitan area, informal and backyard shacks are almost entirely without piped water within the dwelling structure. There are substantial variations in access to water supply between the four metropolitan centres.

[16] The category other includes township taps, boreholes, trucks and water from neighbouring houses. In the case of Cape Town, the category of 'other' refers to taps at communal sites and may include street taps.

Chapter 5
CONSUMPTION DATA

5.1 Introduction

The aim of this chapter is to present a picture of end-use energy consumption for the different dwelling type categories and for electrified and non-electrified households in the four focus areas. This chapter moves from the general to the specific; firstly giving a broad picture of the frequency of occurrence of fuels used in the different areas and for specific end-uses; and secondly giving a more detailed breakdown of end-use consumption for typical low-income household fuel scenarios. The following data is presented for each end-use category:

- quantity of fuel used per end-use;
- energy content of fuel used per end-use; and
- cost of fuel per end-use.

5.1.1 Data sources

Data presented in this chapter was predominantly drawn from two different types of sources - firstly, the energy consumption studies conducted by Rossouw and van Wyk (1993), Hoets and Golding (1992) and Mehlwana and Qase (1996) in the different focus areas and secondly, from the South African Labour and Development Research Unit's (SALDRU's) Project for Statistics on Living Standards and Development (PSLSD). Where appropriate, data is drawn from other sources to substantiate the findings of the above-mentioned surveys.

The consumption data for both Gauteng and the Durban Region is based on information presented in the Hoets and Golding (1992) survey. The data was presented by fuel and dwelling type and has been manipulated and updated to give a picture of end-use energy consumption for 1995/1996. The Gauteng data is drawn from three areas - Alexandra, Zonkesizwe and Orange Farm. The dwellings are categorised into three groups - formal houses, planned shacks and unplanned shacks. The consumption data for the Durban Region is drawn from Umlazi, Kwa Mashu and Inanda/Newtown. In the Hoets and Golding study, the dwellings were categorised into three groups - formal houses, planned informal houses and informal shacks, with no distinction being made between planned and unplanned shacks. For the purposes of this study, dwellings in the Durban Region have been categorised into two types - formal and informal dwellings - with informal houses and informal shacks being combined into one category. While backyard shacks do occur in these areas, they were excluded from the original data base owing to a statistically insignificant sample size. The data for Port Elizabeth is drawn from the Rossouw and van Wyk (1993) study which surveyed the area of Ibhayi (New Brighton, Kwazakele, Zwide and Soweto by the Sea). Cape Town's consumption data is drawn predominantly from Mehlwana and Qase's (1996) study of social determinants for energy use in low-income households in the Western Cape. This study provides a descriptive analysis of energy consumption in households surveyed in Langa and Khayelitsha. The data for Port Elizabeth and Cape Town is categorised into formal houses and planned informal, unplanned informal and backyard shacks.

Information derived from the above-mentioned studies on energy consumption in low-income households is augmented with data drawn from the SALDRU Project of Statistics for Living Standards and Development (PSLSD) (1993). The metropolitan data collected in the PSLSD coincides with the four metropolitan areas - Cape Town, Port Elizabeth, Durban and Johannesburg (Gauteng) - identified as the focus areas of this study. The PSLSD presents a picture of energy consumption in electrified and non-electrified households and between the different income groups in the four metropolitan areas. It is important to note at the outset that the PSLSD data for electrified households focuses on higher income, long-established electrified households. The picture for newly electrified, lower income houses has proven to be very different, as will become apparent later.

5.1.2 Problems with survey data

As mentioned previously, the paper draws solely on existing survey material. It is necessary, therefore, to highlight some of the generic problems associated with the focus of these surveys, the selected categories of data, the compatibility of the different surveys and the depth and accuracy of the analysis.

The stated focus of this paper is to create and analyse end use energy consumption models for the four metropolitan study areas. Instead of honing in on the finer details of end-use energy consumption within the household, the survey material available tends to focus on the broader energy consumption patterns. It is assumed that part of the reason for this is that, statistically, it is easier to extrapolate trends from broad consumption data than from the more detailed and varied information on how energy is utilised within the household. As a result, the surveys tend to focus on the frequency of use of the different fuels and appliances (that is, numbers of people using a particular fuel or appliance), while quantities of fuels used and energy expenditure are broken down by fuel type rather than by end-use. Thus, little concrete data on end-use consumption patterns exists and it has, therefore, been necessary to manipulate data to give a picture of end-use consumption. Furthermore, for each of the four study areas, the survey data is presented and analysed by dwelling type. While there are a number of assumptions built into these categories, these are not made explicit in the survey material. For example, it is clear that the dwelling type categories reflect variations in socio-economic status and levels of poverty, but these connections are seldom made within the surveys. More significantly, differences in dwelling types seem to reflect differences in levels of electrification. While this is likely to influence patterns of consumption in the different dwelling types, none of the surveys explore this relationship. This can lead to erroneous conclusions being drawn. For example, within a particular dwelling category, the variations in consumption patterns between the different metropolitan areas may be attributed to variations in geographic location, while, in fact, they are a result of varied levels of electrification.

The quality of data varies considerably between survey areas. No end-use data is presented in the Hoets and Golding (1992) survey report used to inform the models for Johannesburg and Durban. Fuel data is presented only in terms of frequency of use, monthly costs and quantities consumed per month. Information on appliance ownership and use, together with information on the frequency of use, monthly costs and quantities, was manipulated to make statements about end-use consumption patterns. The Rossouw and van Wyk (1993) report analyses end-use consumption patterns more comprehensively, presenting data on appliance/fuel combinations and the fuels used for various end-uses. Cost and quantity data was, however, scantily presented. While the Mehlwana and Qase (1996) study is a qualitative survey and is, therefore, not statistically sound, it was used extensively to make quantitative assumptions about end-use consumption. Further, the quality of data varies between the different fuel types. For example, more detailed information is presented for electricity than for wood or coal.

None of the survey data is broken down into the consumption patterns of electrified versus non-electrified households nor length of time in residence. This is a serious omission as it makes it difficult to establish trends in consumption as households become electrified. Furthermore, as data is not presented for different income groups and for electrified versus non-electrified households, the average fuel and cost data is biased by extremes in consumption and the data presented is not a wholly representative picture. In order to correct for these omissions, the data drawn from the consumption studies was augmented by data from the PSLSD. In terms of evaluating end-use consumption, the PSLSD survey questionnaire had some limitations. Davis (1995) points to two of these limitations: firstly, expenditure on different fuel categories was assessed without questions detailing quantities and prices of fuels used. This necessitated the drawing of price and quantity information from other sources and attempting to correlate those with the PSLSD data. Secondly, as in the case of the energy consumption studies, respondents were not asked how long they had had electricity and, therefore, the effect of time-since-connection on consumption patterns could not be analysed (Davis 1995). In addition, data for the metropolitan areas was biased toward both formal[1] and electrified households. While weighting was introduced to correct for this oversampling, discrepancies between aggregated totals presented in the SALDRU data and aggregated totals in both the consumption studies and Eskom reports indicate that the biases still exist. Aggregated data for all households in the

[1] Seventy-six percent (76%) of the households sampled in the metropolitan areas were living in formal houses.

metropolitan areas have been avoided due to the reflected bias toward formal electrified houses in these totals. While the data is not wholly representative, it can be used to demonstrate the patterns of energy consumption in electrified versus non-electrified households.

5.1.3 Structure of chapter

As mentioned above, the consumption studies and the PSLSD data focus primarily on frequency of fuel use. No studies exist which evaluate the quantities and/or cost of fuel consumption by end-use. It was thus necessary to analyse existing data on fuel use patterns and make inferences about the break down of energy consumption by end-use. Chapter five thus takes on a three stage structure. In the first stage, data on the frequency of fuel use is analysed to determine the range of and variations in fuels used in the different areas both by dwelling type and by electrified and non-electrified households; multiple fuel use is investigated in electrified and non-electrified households; and the frequency of fuel use by end-use category is also analysed. This data is summarised into a series of scenarios depicting the most common combinations of fuels used to meet the range of household energy needs in the different areas. Levels of appliance penetration are analysed by area and dwelling type and the scenarios are revisited, including information on the most commonly used appliances. Stage two draws together data on fuel prices, energy content, appliance efficiency and the break down of energy consumption by end-use. In stage three, the scenarios are again revisited and a picture of energy consumption by end-use is given. Finally, conclusions are drawn about the relationships between patterns of energy consumption and demographic, socio-economic and climatic variables.

5.2 Frequency of fuel use

This section aims to present a broad picture of fuel use in the different areas and in the different dwelling types. Data is presented on:

- the most commonly used fuels in the different areas by dwelling type and electrified and non-electrified households;
- fuels used to meet the range of household energy needs in the different areas by dwelling type and electrified and non-electrified households;
- multiple fuel use in electrified and non-electrified households; and
- appliance ownership levels in user households.

This data is used to generate scenarios of household fuel use across South Africa.

5.2.1 Multiple fuel use

Multiple fuel use is a widespread occurrence in low-income households in South Africa. Figures 5.1 and 5.2, based on the PSLSD study, show the extent of multiple fuel use in the different metropolitan focus areas and for electrified and non-electrified households.

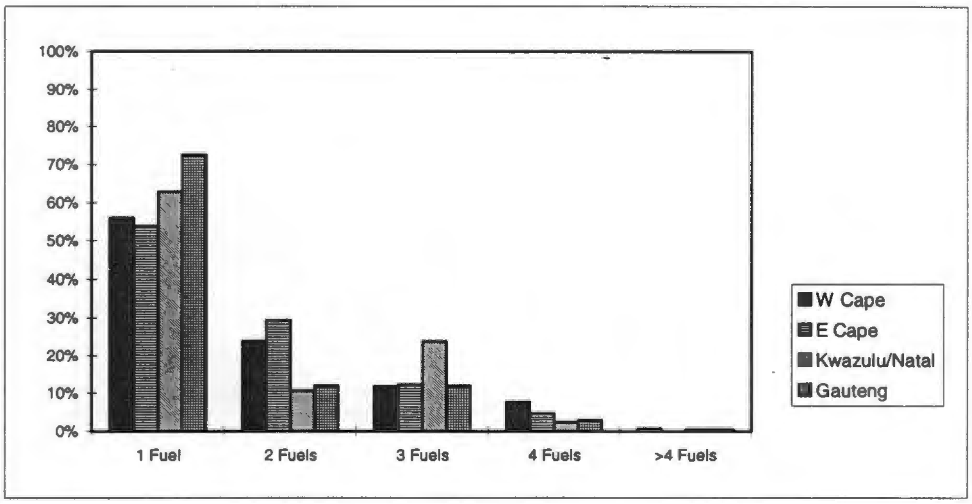

Figure 5.1: Multiple fuel use in the different provinces: Electrified low-income metropolitan households
Source: SALDRU (1993)

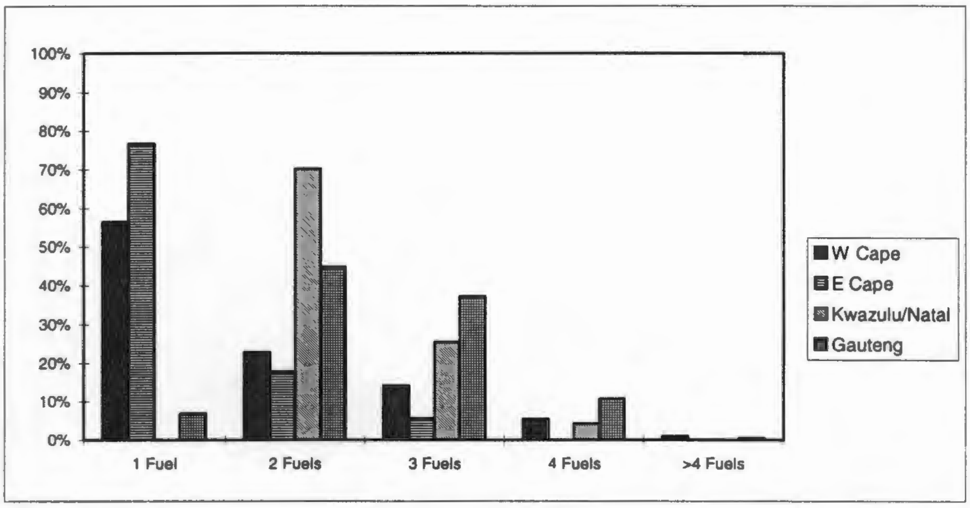

Figure 5.2: Multiple fuel use in the different provinces: Non-electrified low-income metropolitan households
Source: SALDRU (1993)

Figure 5.1 indicates that more than 50% of electrified households in all provinces use only one fuel. The highest occurrence of mono-fuel use is found in Gauteng with 73% of all households using one fuel. Between 20% and 30% of households in the Eastern and Western Cape use two fuels, while in Kwazulu/Natal, 24% of households use three fuels. These figures are likely to reflect the PSLSD's bias toward formal electrified households with a long history of electricity use. In non-electrified households, the picture is very different. A higher proportion of non-electrified households in the Eastern and Western Cape (77% and 57% respectively) use only one fuel. Most households (70%) in Kwazulu/Natal use two fuels, while non-electrified households in Gauteng use two or three fuels (45% and 37% respectively).

5.2.2 Household consumption[2]

The types and combinations of fuels used vary greatly between and within areas. The percentage of households using the different fuels is presented below in terms of dwelling types and electrified versus non-electrified households. These variations are influenced by a number of different factors, including levels of household income, the availability and cost of fuels, access to electricity and length of time in residence.

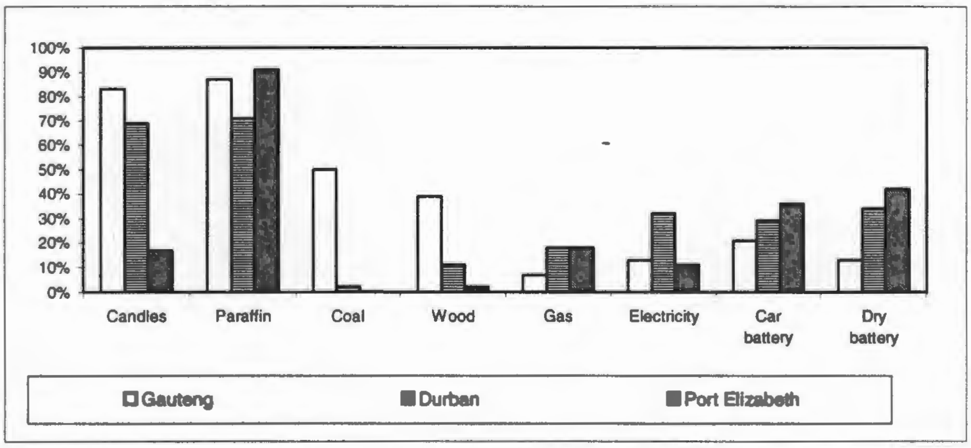

Figure 5.3: Comparison of fuel use in the different provinces: all low-income metropolitan households
Sources: Hoets & Golding (1992); Rossouw & van Wyk (1993)

2 No aggregated data on frequency of fuel use was available for Cape Town and, therefore, the Cape Town data is presented only by end-use.

Figure 5.3 demonstrates the range and predominance of fuel types in the different areas. The types of fuels used are influenced by geographical location in relation to fuel sources and the related issues of availability and cost of fuels. The major trends indicated in this figure are:

- low levels of electrification among all low-income households, with Durban reflecting relatively high levels of access to electricity (this coincides with the levels of urban electrification presented by province in chapter four (table 4.1), which shows the highest levels of electrification to be found in the Western Cape and Kwazulu/Natal). It is important to note, however, that the values presented in figure 5.3 are for 1992/1993 and that, as a result of the national household electrification programme, levels of access to electricity have increased in all areas;
- a predominance of the use of coal in Gauteng;
- a corresponding high incidence wood use in Gauteng which may reflect the practice of igniting coal with wood;
- paraffin is the most widely used fuel in low-income households in all provinces; and
- a much lower incidence of use of candles in Port Elizabeth than in Gauteng or Durban.

Figures 5.4 to 5.6 below present the patterns of fuel use in the different dwelling types in the three metropolitan areas. As mentioned in chapter two, it is clear that the dwelling types themselves do not influence fuels used, but rather a host of social and economic factors such as the structure and permanence (perceived or real) of the household, access to fuels (in terms of geographical location, affordability and, in the case of electricity, connection to the grid) and levels of income. In terms of access to electricity, discrepancies exist between the data presented below and the data presented in chapter four. Levels of electrification are consistently lower in the sample data than in the comparative geographical areas as presented in chapter four. These discrepancies can be attributed, in part, to new electrification which has taken place in the period between 1992/1993, when the surveys were conducted, and 1995, the latest reported data on levels of electrification. It must not be discounted, however, that some of the discrepancies may be attributed to the sample selected not being truly representative of the area.

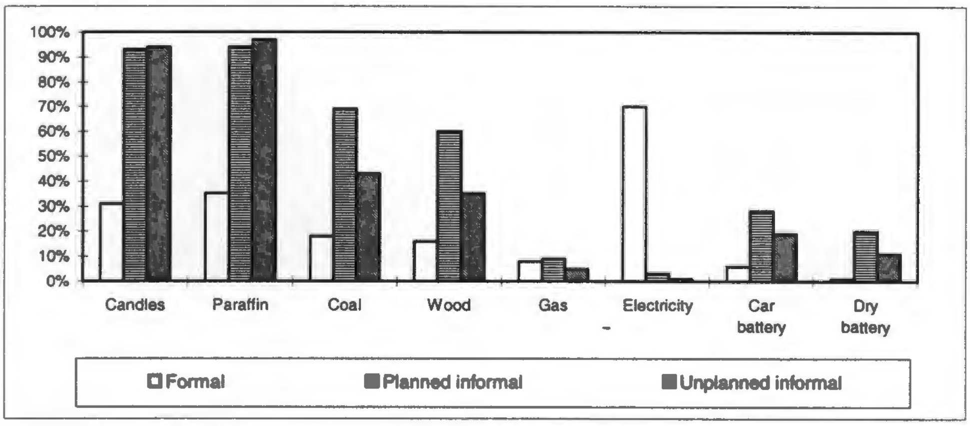

Figure 5.4: Percentage fuel use in Gauteng: by dwelling type
Source: Adapted from Hoets & Golding (1992)

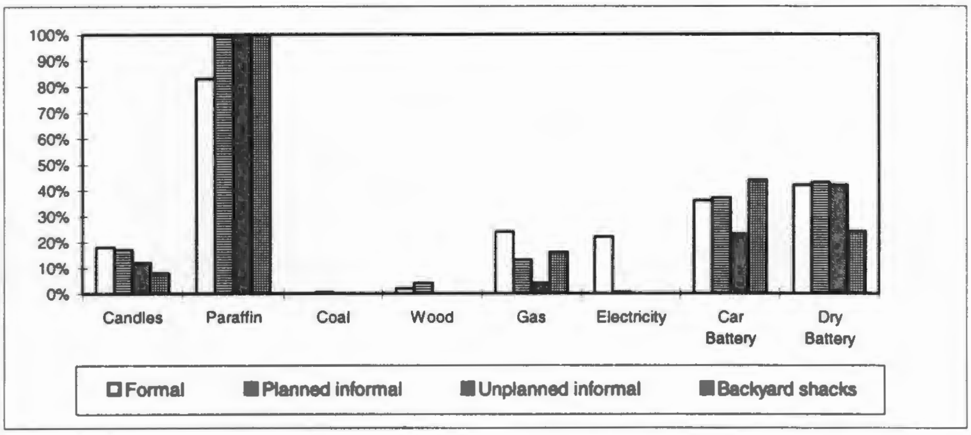

Figure 5.5: Percentage fuel use in Port Elizabeth: by dwelling type
Source: Rossouw & van Wyk (1993)

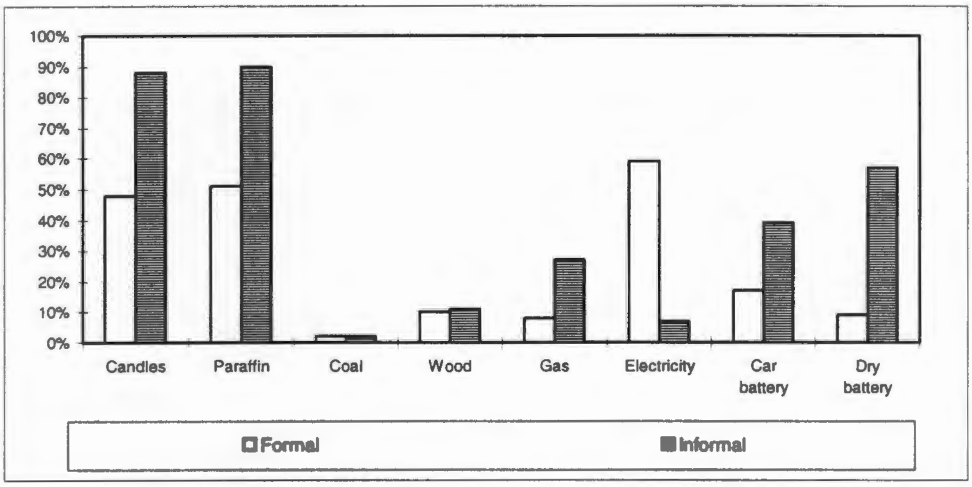

Figure 5.6: Percentage fuel use in Durban: by dwelling type
Source: Adapted from Hoets & Golding (1992)

Levels of electrification are much higher in the formal than in the informal dwellings sampled. As a result, differences in fuel consumption patterns in the formal and the informal categories may largely reflect levels of access to electricity. In the formal housing category, the lowest levels of electrification are experienced in Port Elizabeth. This reflects national trends in electrification (as shown in table 4.2 in chapter four). In the informal dwelling category, the highest levels of electrification were found in Durban. These provincial variations in levels of electrification in the different dwelling types have further implications for patterns of fuel use. The following observations support the above argument:

- A greater proportion of informal than formal households use paraffin. It is likely that this reflects the varied levels of electrification in the different dwelling types. A noticeable exception is that of Port Elizabeth, where more than 80% of formal dwellings use paraffin. This high incidence of paraffin usage among formal households may be attributed to the lower level of electrification in formal dwellings in Port Elizabeth. The lowest incidence of paraffin use in formal dwellings is found in Gauteng. This may be attributed to the higher levels of electrification and the wider use of coal.
- With the exception of Port Elizabeth, there is a much higher use of candles among informal dwellings than formal dwellings. This is likely to reflect the lower levels of electrification in informal dwellings and the act of substituting candles with electricity in electrified houses.
- The highest incidence of use of car batteries occurs among informal dwellings. Substantial use of car batteries is found among formal households in Port Elizabeth. This can be attributed to the lower levels of electrification in the Eastern Cape.
- The highest use of dry batteries is found among informal dwellings in Port Elizabeth and Durban, while among formal dwellings, the highest use is found in Port Elizabeth.

- As mentioned previously, the use of coal is almost exclusive to the Gauteng region. There is a higher incidence of use in informal than in formal dwellings.

There are no clear trends in the use of gas between the different dwelling types. In Port Elizabeth, there is a greater use in formal houses, while in Durban, there is a greater use in informal houses. The lowest incidence of use occurs in Gauteng.

As stated above, access to electricity plays a significant role in fuel consumption patterns. Figures 5.7 and 5.8 below demonstrate the variations in fuel consumption patterns in electrified and non-electrified households in the different provinces.

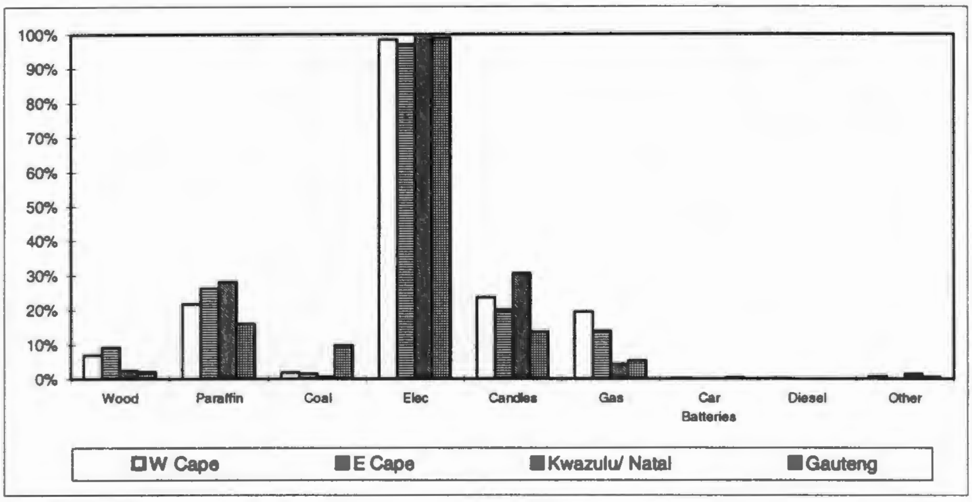

Figure 5.7: Fuel use in the different province: Electrified low-income metropolitan households
Source: SALDRU (1993)

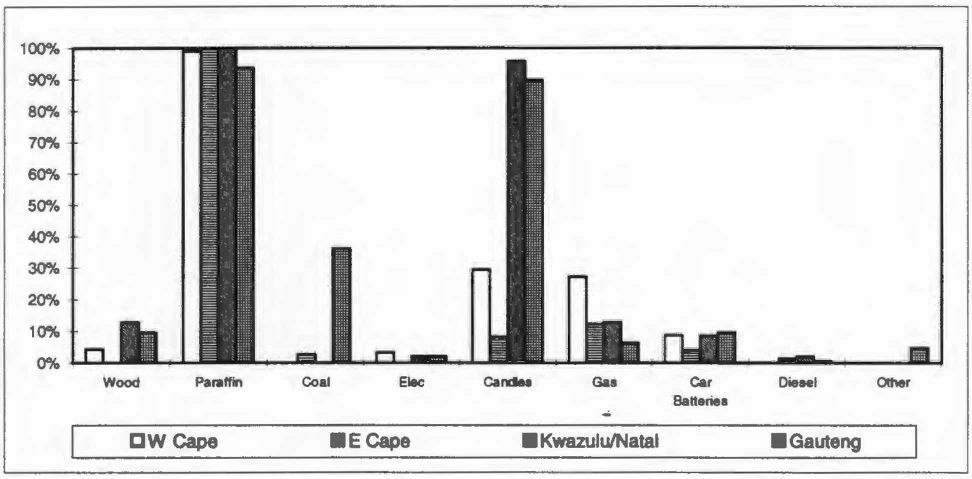

Figure 5.8: Fuel use in the different provinces: non-electrified[3] low-income metropolitan households
Source: SALDRU (1993)

Figure 5.7 demonstrates that the most frequently used fuel in electrified households is electricity. However, many electrified households use a combination of fuels to meet the range of household needs. The mixture of fuels used varies between areas. Between 20% and 30% of low-income electrified households in Cape Town, Port Elizabeth and Durban use paraffin and/or candles. Between 15% and 20% of electrified households in Cape Town and Port Elizabeth use gas. In Gauteng, between 10% and 20% of electrified households use paraffin, coal

[3] It is noted that the category of *non-electrified* households includes some households which have access to electricity. This is a result of the wording of the questionnaire, which asked, 'Is the housed connected to an electricity supply?' Respondents answers were dependent on their perceptions of *connection*. While some respondents perceive a connection as mere access, others perceive it as formal connection to the grid. This accounts for the non-zero values for electricity use in 'non-electrified' households.

and/or candles. When compared to data for electrified households from other consumption studies, the SALDRU (1993) figures for the use of fuels other than electricity appear to be relatively low. These discrepancies can be attributed to the focus of PSLSD study on formal, higher income households with a relatively long history of electricity use. While the frequency of fuel use may vary between the studies, the trends in fuel use presented in figure 5.7 reflect trends in other consumption studies. In non-electrified households, higher levels of multiple fuel use exist. While paraffin is the dominant fuel in all provinces, with over 90% of households using paraffin, high incidences of use of other fuels is common. More than 90% of non-electrified households in Durban and Gauteng use candles. Between 20% and 30% of low-income non-electrified households in Cape Town use candles and/or gas. In Gauteng, non-electrified households were found to use coal. Significant differences between electrified and non-electrified households revolve around the substitution of fuels, specifically with regard to the substitution of electricity with car batteries in non-electrified households.

From the analysis of frequencies of fuel use in the different metropolitan areas, it is possible to draw out a series of scenarios representing the most common combinations of fuels used in low-income households across South Africa. While levels of consumption vary between the different dwelling types and income groups, the combinations of fuels used can be split between the categories of electrified and non-electrified. The following scenarios emerge:

In *electrified* households,

- Single fuel use of electricity is found in over 50% of households in all four metropolitan areas, with the highest levels being found in Gauteng (73%) and Durban (63%). The consumption levels vary substantially in these households and are dependent on the interconnected variables of income, time-since-connection and levels of appliance acquisition.
- The combined use of electricity and paraffin is found in many electrified households across South Africa. This is most apparent in Cape Town and Port Elizabeth.
- The combined use of electricity and gas is found in Durban, Port Elizabeth and Cape Town.
- In Durban, the combined use of candles, electricity and paraffin is a common occurrence among low-income electrified households.

In *non-electrified* households,

- In Port Elizabeth and Cape Town, a large proportion of households (77% and 57% respectively) use paraffin as the sole household fuel.
- In Durban and Gauteng and to a lesser degree in Cape Town and Port Elizabeth, many non-electrified households use a combination of paraffin and candles.
- In Gauteng, many non-electrified households use a combination of paraffin, candles and coal.
- Car and dry batteries are used extensively by non-electrified households to meet the need for media services and can be added to any of the above household fuel-use scenarios.

The scenarios presented above are highly aggregated and do not include information on end-use energy consumption. The following section explores broad patterns of fuel use by end-use. The end-uses are broken down into cooking, lighting and space and water heating and analysed by area, dwelling type and electrified versus non-electrified households. The scenarios outlined above are revisited and analysed in terms of fuels used to meet different household needs.

5.2.3 Percentage of fuels used for different end-uses

The full range of household energy needs includes the following end-uses:

- cooking;
- space heating;
- water heating;
- lighting;
- refrigeration;
- entertainment; and
- ironing.

In low-income households, the full range of energy needs are often not met. Specifically, refrigeration, space heating and entertainment services may be lacking in low-income households. This is influenced predominantly by the types of fuels used in the household and the prohibitive cost of appliances. Furthermore, in the case of space heating, climate has been found to influence consumption patterns. In more moderate coastal climates there is less of a need for space heating than in the cold interior climatic areas (Eberhard & Trollip 1994).

It is important to note that the sources of data used below are presenting different types of information. The PSLSD data (SALDRU 1993) refers to the primary or main fuel used by households to meet the different end-uses, while the consumption study data (Hoets & Golding 1992, Rossouw & van Wyk 1993 and Mehlwana & Qase 1996) refers to all fuels used by households to meet the different end-uses. The consumption study data, therefore, reflects multiple-fuel use, while the PSLSD data does not. This should be borne in mind in subsequent sections.

5.2.3.1 Cooking

Williams (1993: 28) states that cooking is 'arguably the most important energy service sought by households, as it renders many foodstuffs edible, and is therefore fundamental to people's welfare'. The types of fuels used for cooking vary substantially between areas and between electrified and non-electrified households. These regional and household variations are highlighted below.

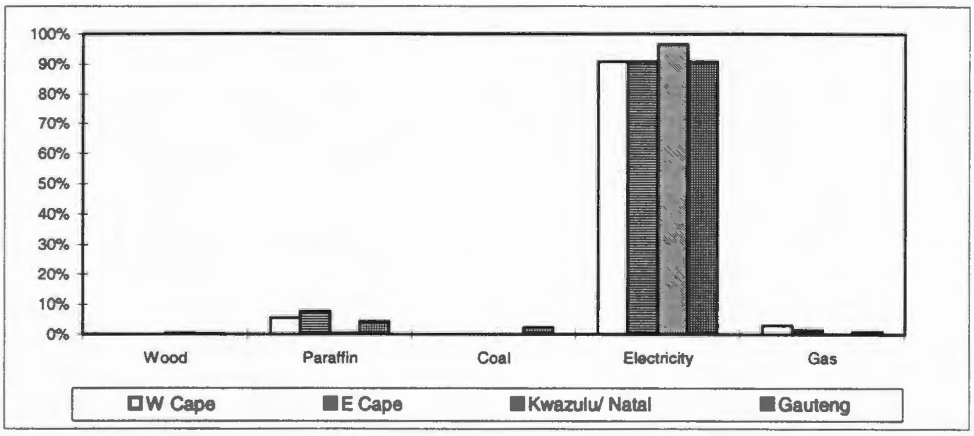

Figure 5.9: Primary fuel used for cooking in electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

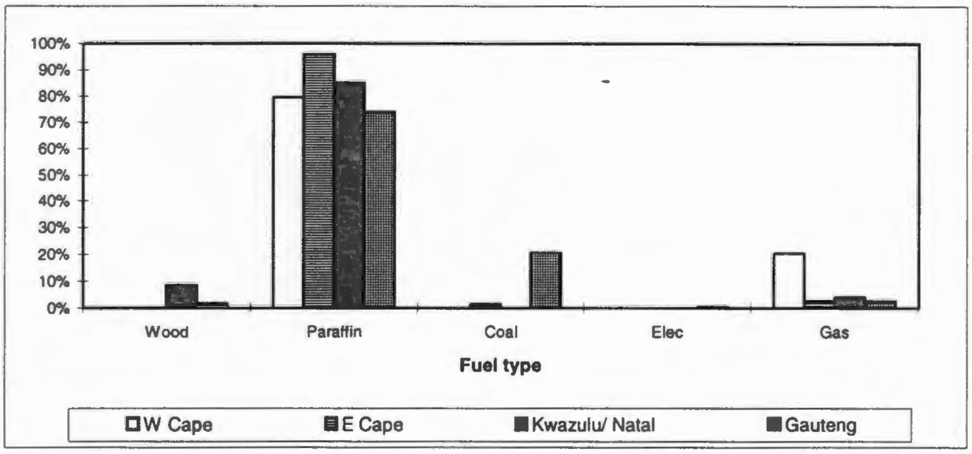

Figure 5.10: Primary fuel used for cooking in non-electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

Figures 5.9 and 5.10 show the primary fuel used for cooking in electrified and non-electrified households. Figure 5.9 demonstrates that a high proportion of electrified households use electricity as their primary cooking fuel, while less than 10% of these households use paraffin, gas, coal and wood. While the relative dominance of electricity as a cooking fuel can, in part, be attributed to the fact that figure 5.9 presents primary fuel use only, other consumption studies found much higher usage levels of other fuels in electrified households. For example, Gervais (1987) found that 67% of electrified households in Soweto continue to cook with coal and Mehlwana & Qase (1996) found that electrified households surveyed in Cape Town predominantly use gas and paraffin for cooking (see figure 5.14). Thus, it is clear that figure 5.9 reflects the PSLSD study focus on long-established electrified households.

Figure 5.10 demonstrates that in non-electrified households, a wider range of fuels are used for cooking. While paraffin is the most frequently used primary fuel in non-electrified households across all the provinces, variations exist in the frequency of occurrence and in the use of other fuels between provinces. In the Eastern Cape, there is little variation in the primary fuel used by non-electrified households with paraffin being used by 96% of the households. In the Western Cape, 79% and 21% of non-electrified households use paraffin and gas respectively as the primary fuel for cooking.

In Gauteng, paraffin (74%) and coal (21%) are the primary fuels used for cooking. It is important to note that the low-levels of coal usage reported in the Gauteng area may reflect seasonal variations in coal use. Evidence suggests that coal-using low-income households shift from using coal in winter to paraffin in summer to avoid the space heating effects of coal use (PDG 1995). In stark contrast to the observations made in the PSLSD study, Kessel (1988) found that 63% of informal households in Gauteng use coal for cooking. In Kwazulu/Natal, 85% of non-electrified households use paraffin as their primary cooking fuel. Wood (9%) and gas (4%) are also used by households in Kwazulu/Natal.

In contrast to the SALDRU (1993) data which analyses primary fuels only, figures 5.11 to 5.14 below present a picture of multiple fuel use by dwelling type in the different metropolitan areas.

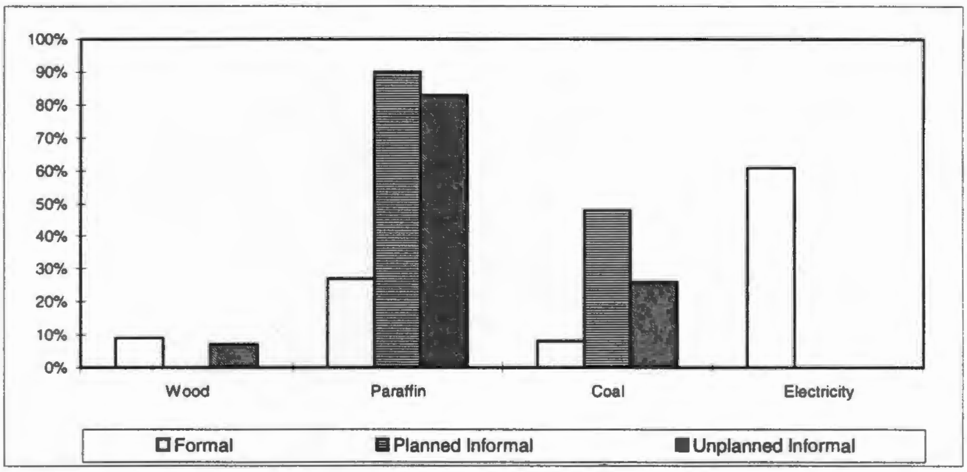

Figure 5.11: All fuels used for cooking in Gauteng
Source: Adapted from Hoets & Golding (1992)

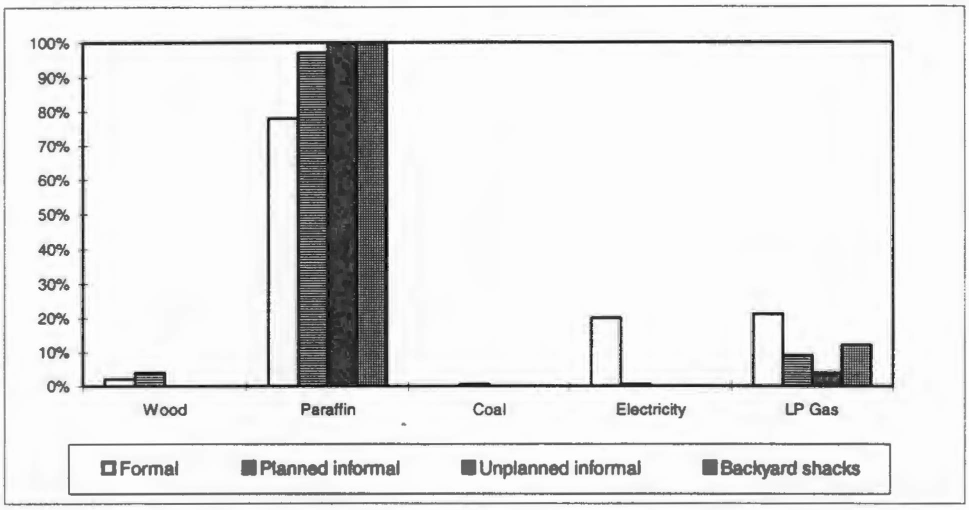

Figure 5.12: All fuels used for cooking in Port Elizabeth
Source: Rossouw & van Wyk (1993)

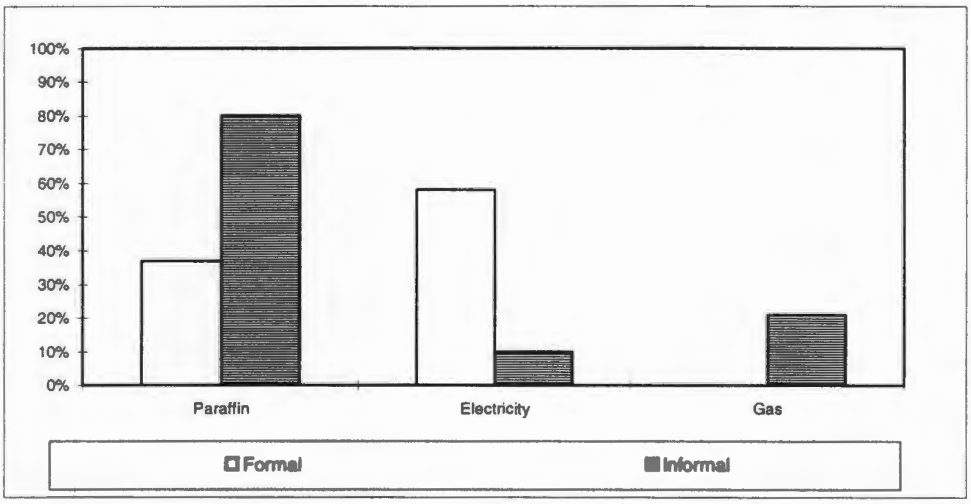

Figure 5.13: All fuels used for cooking in Durban
Source: Adapted from Hoets & Golding (1992)

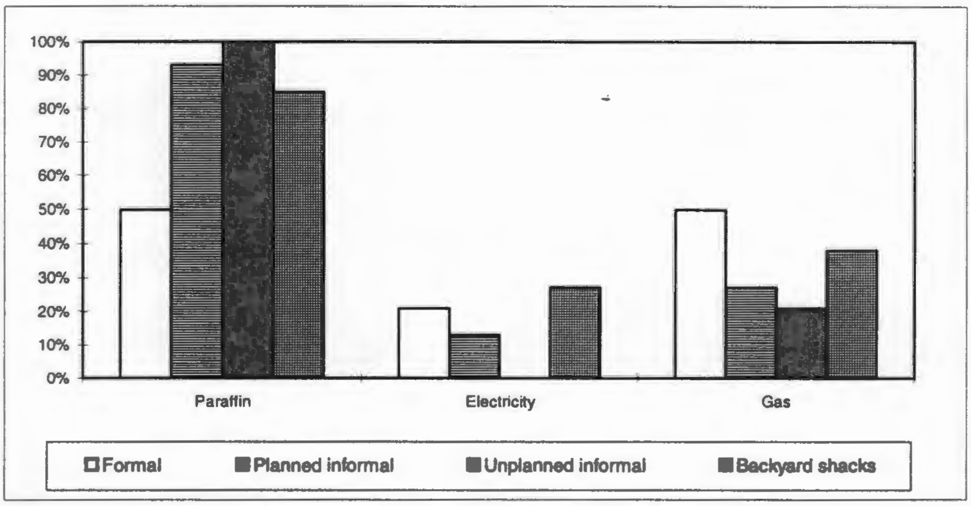

Figure 5.14: All fuels used for cooking in Cape Town
Source: Mehlwana & Qase (1996)

On a broad level, the above figures reflect the variations in fuels used in the different regions. They show the higher use of coal in Gauteng and the use of gas in Port Elizabeth, Durban and

Cape Town. Figures 5.11 to 5.14 also reflect variations between dwelling types within the focus areas.

In formal dwellings in Gauteng and Durban, electricity, and to a lesser degree paraffin, is used for cooking. Coal is also used by formal dwellings in Gauteng. The Hoets and Golding (1992) study was conducted in summer and reflects the shift from using coal in winter to using paraffin in summer mentioned earlier. Gervais (1987) found that 63% of electrified households cooked on a coal stove, 50% of these households also using them in summer. In Cape Town and Port Elizabeth, paraffin, gas and electricity are used for cooking in formal dwellings. The data presented in figure 5.14 for Cape Town represents formal electrified households. Macroplan (1992) found that 67% of formal non-electrified households in Khayelitsha use gas for cooking.

In informal dwellings (both planned and unplanned) in Cape Town and Durban, paraffin, and to a lesser degree gas, are used for cooking. In Port Elizabeth, paraffin is used almost exclusively, while in Gauteng, paraffin and coal are used for cooking. This is substantiated by Kessel (1988), DRA (1989) and the EPRET database which found that paraffin is used by between 50% and 99% of informal households in the Port Elizabeth and Cape Town regions and that similar levels of use are found in the Durban Functional Region (DFR). Furthermore, it was found that 24% of all households in Cape Town and in the DFR, 20% of informal households use LPG for cooking (Kessel 1988, EPRET database).

In backyard shacks in Port Elizabeth, paraffin is used for cooking, while in Cape Town, paraffin, gas and electricity are used.

5.2.3.2 Lighting

While lighting contributes a relatively small amount to the household energy load, it has a very high utility, improving the welfare and opportunities of low-income households. There are strong variations between regions and between electrified and non-electrified households in the fuels used for lighting. These variations are highlighted below.

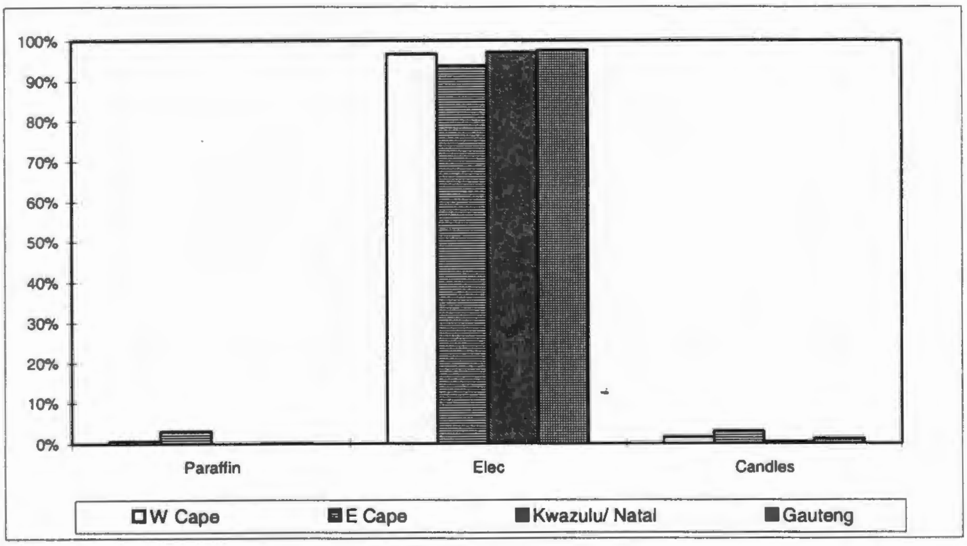

Figure 5.15: Primary fuel used for lighting in electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

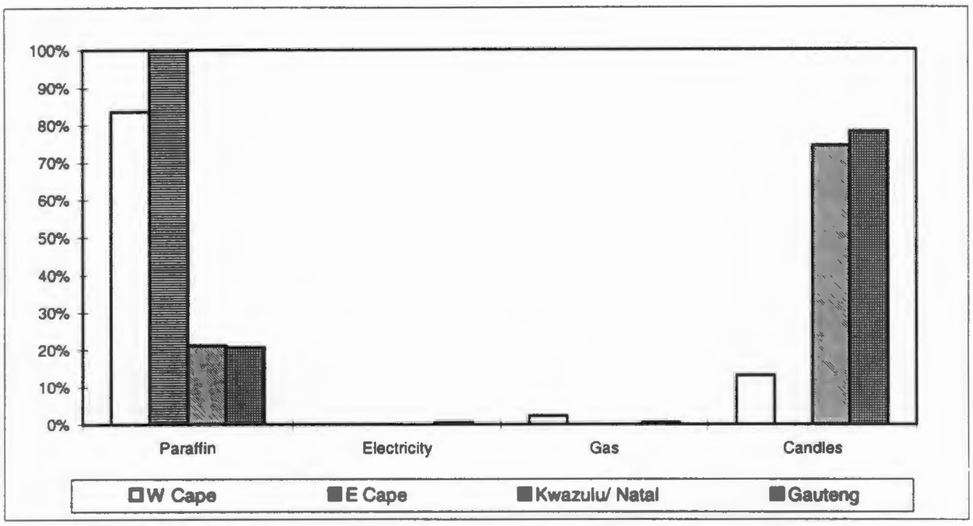

Figure 5.16: Primary fuel used for lighting in non-electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

Among electrified households, the primary fuel used for lighting is electricity. In non-electrified households, significant variations exist between regions. In the Eastern and Western Cape, most non-electrified households use paraffin, while in Gauteng and Kwazulu/Natal, most non-electrified households use candles as their primary fuel for lighting.

The data presented by dwelling type in the consumption studies corresponds with the SALDRU (1993) data on electrified and non-electrified households, reflecting the greater use of candles in Durban and Johannesburg than in Cape Town and Port Elizabeth.

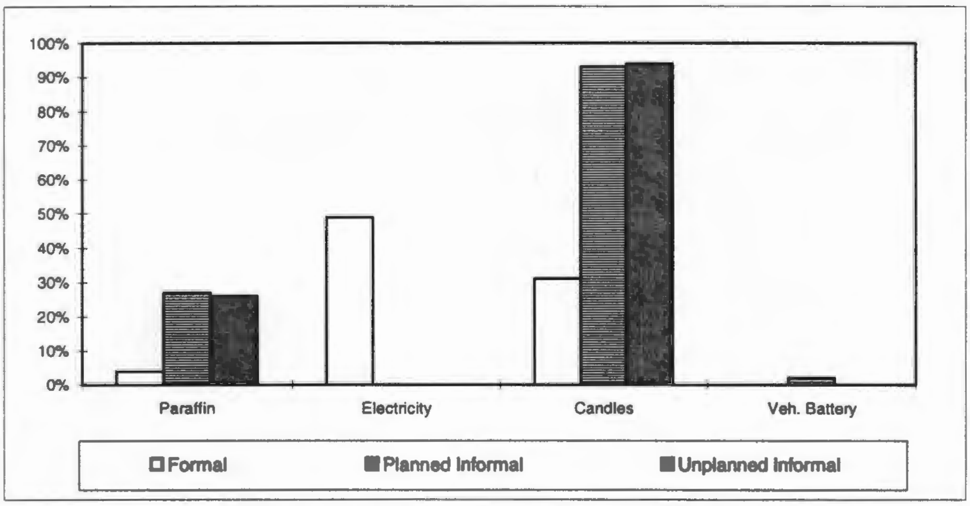

Figure 5.17: All fuels used for lighting in Gauteng
Source: Adapted from Hoets & Golding (1992)

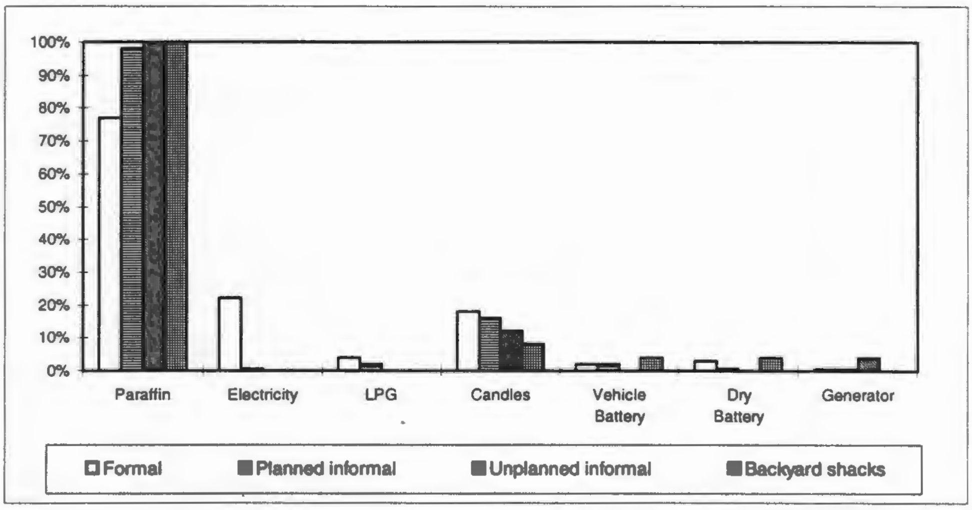

Figure 5.18: All fuels used for lighting in Port Elizabeth
Source: Rossouw & van Wyk (1993)

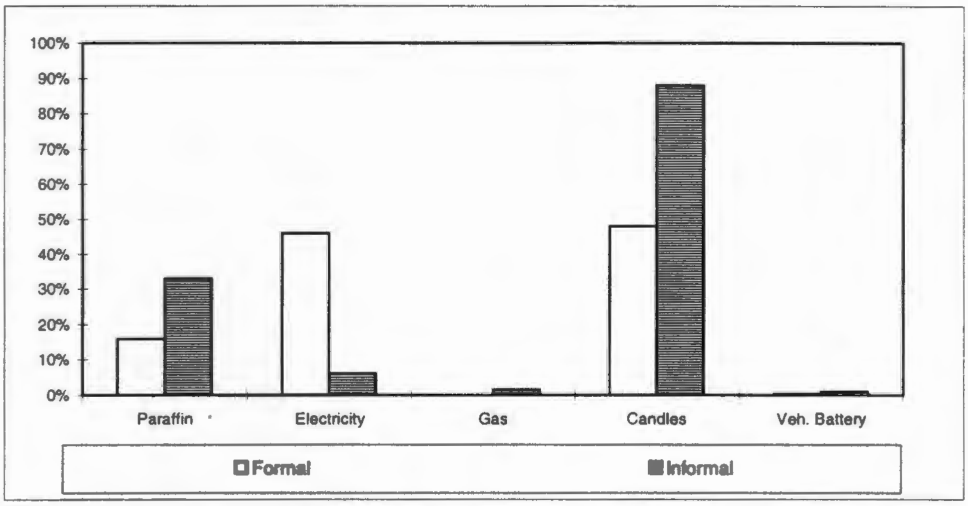

Figure 5.19: All fuels used for lighting in Durban
Source: Adapted from Hoets & Golding (1992)

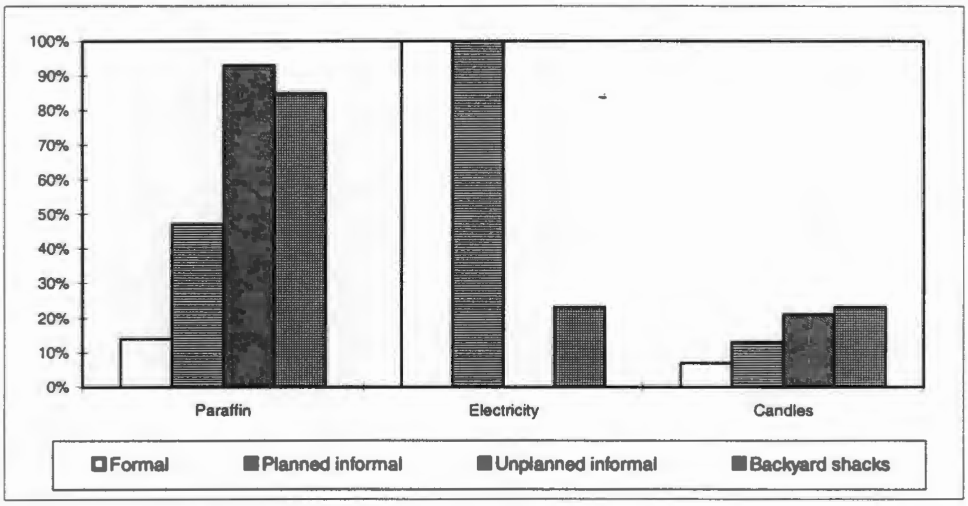

Figure 5.20: All fuels used for lighting in Cape Town
Source: Mehlwana & Qase (1996)

Fuels used for lighting are influenced by two main factors: access to electricity and geographic location. Dwelling type has little implication for use of lighting fuels, but rather reflects levels of access to electricity. While electrified households use electricity as their main fuel for lighting (see figure 5.15), wide-scale multiple-fuel use is evident. In many cases, electrified dwellings are not fully wired and, therefore, paraffin or candles are used in non-wired rooms.

Figures 5.17 to 5.20 above demonstrate the variations in fuel use for lighting between dwelling types in the different focus areas, reflecting levels of access to electricity. In formal dwellings in Durban and Gauteng, electricity and candles are used for lighting. In Cape Town, the formal dwellings sampled were found to use electricity for lighting almost exclusively. In Port Elizabeth, paraffin, and to a lesser degree electricity, was used for lighting in surveyed households.

In informal dwellings in Durban and Gauteng, candles, and to a lesser degree paraffin, are used for lighting. In informal dwellings in Port Elizabeth, paraffin is used for lighting. The Cape Town example demonstrates the link between electrification and fuels used for lighting. Electrified planned informal dwellings use electricity and paraffin, while non-electrified unplanned informal dwellings use paraffin only.

5.2.3.3 Space heating

The use of fuel for space heating is strongly linked to the variable of climate and thus regional variations exist in terms of frequency of use. Furthermore, the types of fuels used vary from region to region and between electrified and non-electrified households in response to the cost and availability of fuels.

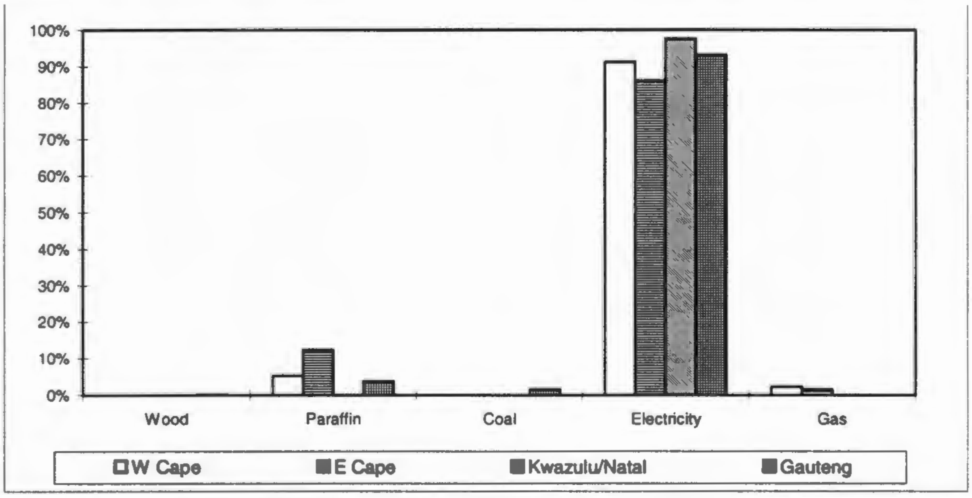

Figure 5.21: Primary fuel used for space heating in electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

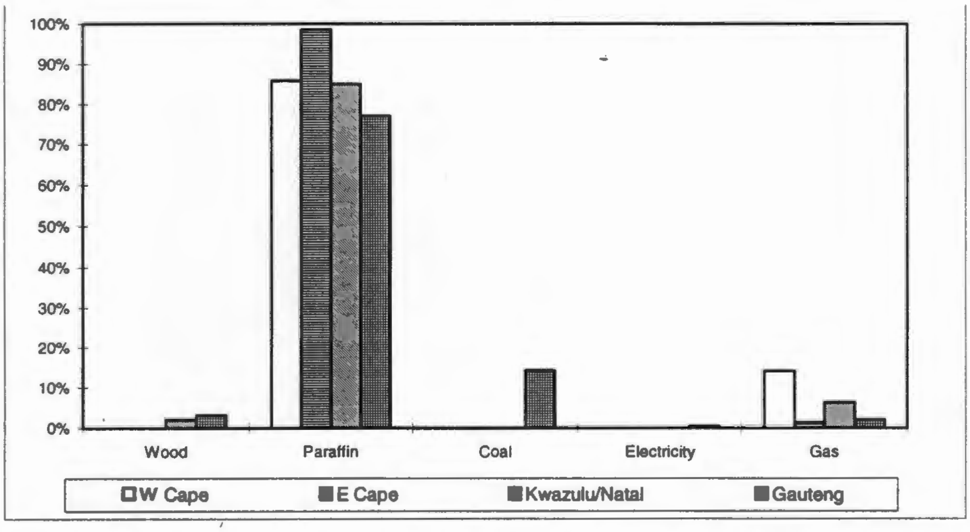

Figure 5.22: Primary fuel used for space heating in non-electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

The PSLSD data presented in figure 5.21 shows that electrified households use electricity as their primary source of fuel for space heating. Once again it is necessary to make the distinction between higher income, long-established electrified households and lower income, newly electrified households. Figures of ownership of electric heaters presented in Williams (1993) indicate much lower levels of use of electricity for space heating. Williams (1993) cites Gervais (1987) who found that 64% of electrified households surveyed in Soweto had electric heaters. Thorne and Theron (1993) found that 44% of households in Khayelitsha, 28% of households in Langa and 59% of households in Guguletu had electric heaters. In Port Elizabeth, only 27% of electrified households used electric heaters (Rossouw & van Wyk 1993). In non-electrified households, the primary fuel used for space heating is paraffin, although some variations exist between regions. In the Eastern Cape, most households use paraffin as their primary fuel for space heating. In the Western Cape, gas is used for space heating in 14% of the households. In Gauteng, coal is the primary fuel used for space heating in 14% of the households. The figures for coal appear to be very low. Other data sources indicate much higher levels of use of coal for space heating. Williams (1993) cites Kessel (1988) who found that paraffin and coal are used by 42% and 39% of households respectively on a national basis. Regional differences in fuel use were also apparent. Coal was found to be more important in Gauteng, with 48% of all households using coal for space heating. In the Cape, paraffin was used by 72% of the households. Another important observation that emerges out of the Williams (1993) report is the low space heating requirements found in the warmer regions of Durban and Port Elizabeth. Only 53% of households in Natal mentioned the need for space heating and only 29% of households in the Port Elizabeth survey conducted by Rossouw and van Wyk (1993) responded to questions on space heating.

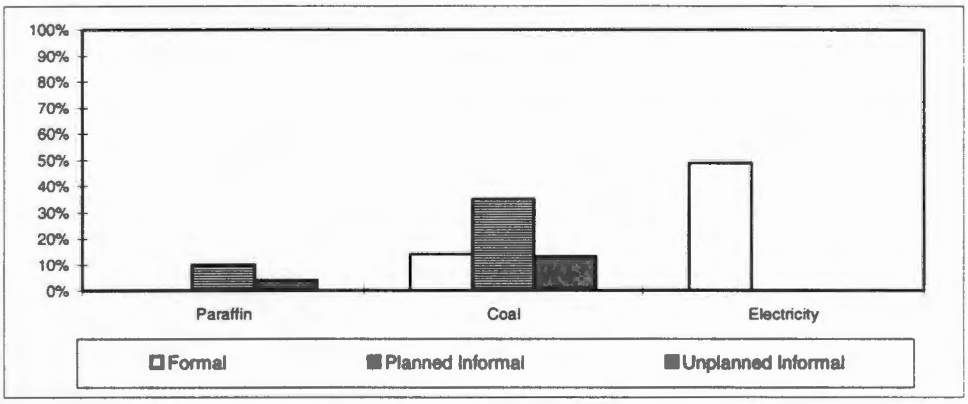

Figure 5.23: All fuels used for space heating in Gauteng
Source: Adapted from Hoets & Golding (1992)

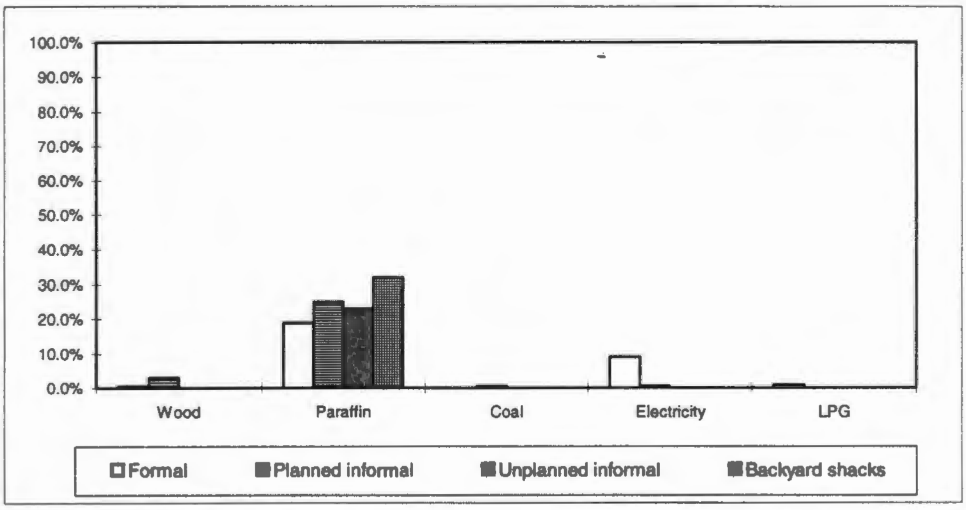

Figure 5.24: All fuels used for space heating in Port Elizabeth
Source: Rossouw & van Wyk (1993)

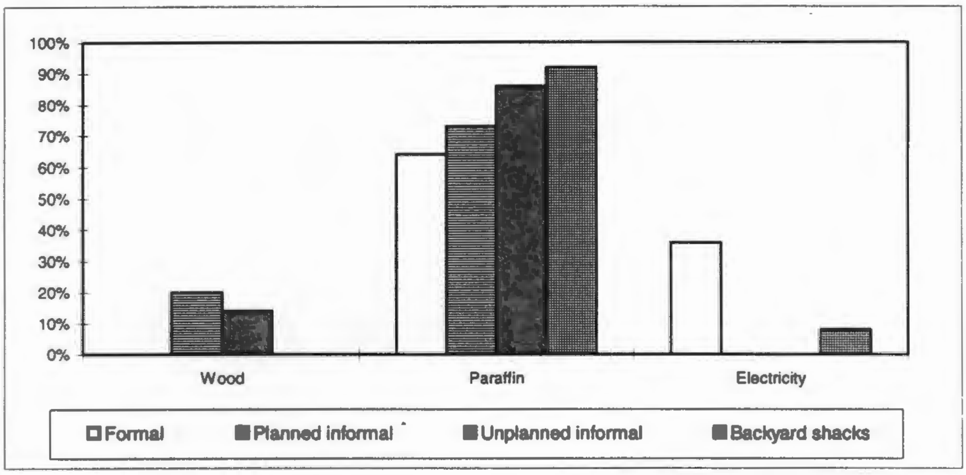

Figure 5.25: All fuels used for space heating in Cape Town
Source: Mehlwana & Qase (1996)

Discrepancies with regard to fuels used for space heating are apparent in the different data sources. Firstly, there is no reference to gas in the consumption study data presented in figures 5.23 to 5.25 above. Secondly, the Hoets and Golding (1992) study identifies coal as the main fuel-source for space heating in non-electrified households,[4] while the SALDRU (1993) study found paraffin to be the primary fuel used for space heating. These discrepancies may be ascribed to the fact that the SALDRU (1993) study investigates primary fuel use only, while Hoets and Golding (1992) report on the frequency of use of all fuels and include multiple fuels to meet a singular end-use. Data for Durban was not available, but Kessel (1988) found that most households in Natal use paraffin as a fuel source for space heating.

5.2.3.4 Water heating

Fuels used for water heating are closely linked to fuels used for cooking and vary accordingly between regions and between electrified and non-electrified households.

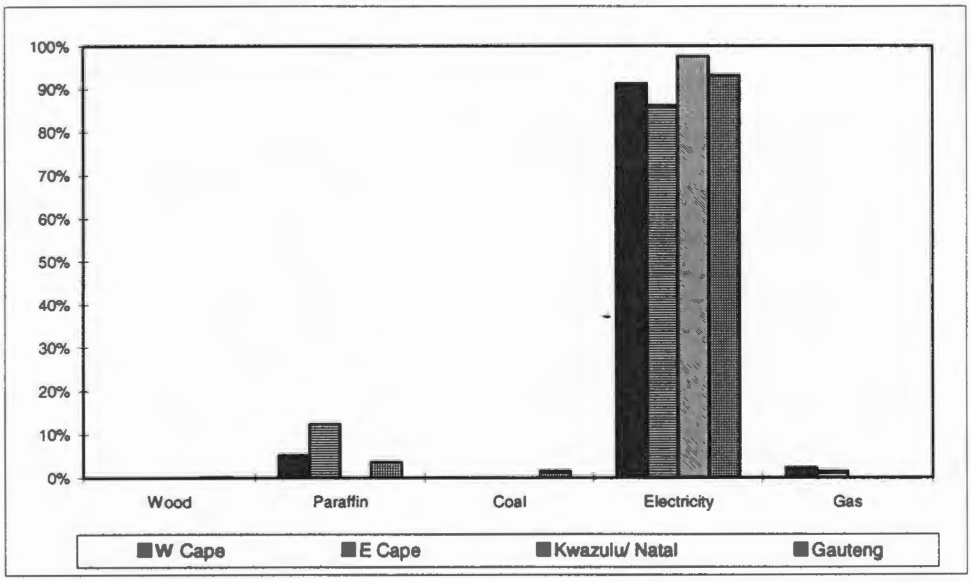

Figure 5.26: Primary fuel used for water heating in electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

4 Very few informal dwellings sampled in Gauteng had access to electricity and, therefore, these dwellings can be considered representative of non-electrified households.

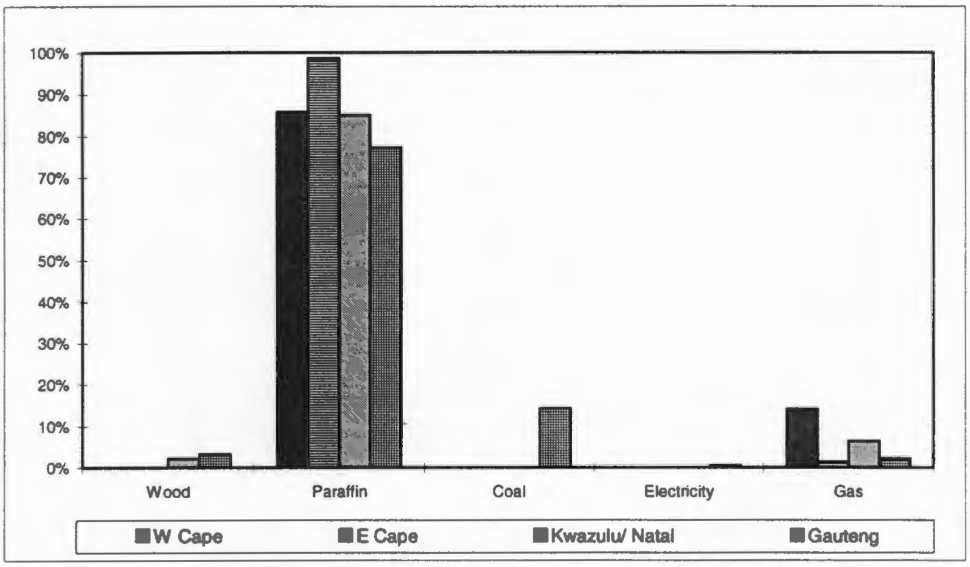

Figure 5.27: Primary fuel used for water heating in non-electrified low-income metropolitan households in the different provinces
Source: SALDRU (1993)

The PSLSD study found that the primary fuel used for water heating in electrified households is electricity. Again, it is necessary to point out that this data refers to long-established electrified households. Furthermore, it is necessary to evaluate the purpose for which water is being heated and how water is heated. Few low-income electrified households own geysers[5]. Kettles, urns and stoves are used to heat water for different purposes. Those households who do not use electric stoves/hot plates are unlikely to use electricity for the purpose of heating water for bathing or washing clothes. In non-electrified households, paraffin is the primary fuel used. Coal in Gauteng and gas in the Western Cape, and to a lesser degree, Kwazulu/Natal, are also used for water heating. The use of coal for water heating purposes once again appears to be very low. Trends in fuel use for water heating are likely to reflect trends in fuel use for cooking as the same appliances are usually used to meet the two end-uses (Leach & Gowen 1987 cited in Williams 1993). Uken and Sinclair (1991) found that, nationally, 45% of households used paraffin for water heating. In the 'Vaal triangle', 50% of households used coal, with the balance using paraffin and electricity. In Soweto, 61% of households were found to use electricity for the purpose of water heating.

From the analysis above, it is possible to distil a more comprehensive picture of how households use fuels to meet the different end-uses. Again, this is presented in terms of electrified versus non-electrified households.

The SALDRU (1993) data presented above shows that in electrified households, the primary fuel used to meet all household activities is electricity. Data drawn from the consumption studies shows greater variations in fuel use in electrified households as well as substantial multiple fuel use. The following broad trends are observed.

In *electrified* households:

- The SALDRU (1993) study identifies electricity as the main fuel used for the purposes of cooking in all electrified households. Other consumption studies point to a wider range of fuels varying on a regional basis. In Cape Town and Port Elizabeth, paraffin, electricity and gas are used to perform household cooking activities and in Gauteng, paraffin, electricity and coal are used for cooking. In newly electrified households one is likely to find fewer electrical cooking appliances and a wider use of other fuels.

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5 Only 19% of the low-income urban households surveyed by Hoets & Golding (1992) were found to have electric geysers. Gervais (1987) found that 23% of electrified households in Soweto owned geysers, while a further 30% used pots on the stove to heat water. Thorne and Theron (1993) found that 65% of electrified households surveyed in Khayelitsha had electric geysers, while only 10% of households in Langa and Guguletu had them installed.

- Most electrified households use electricity to fulfil their lighting needs. Candles and paraffin are, however, still used in electrified households. This is predominantly due to limited wiring of households and the fact that not all rooms have electricity. There is strong evidence to suggest that candles are more common in Gauteng and Durban, while paraffin is a more common lighting fuel in Cape Town and Port Elizabeth.
- The SALDRU and consumption study data bases vary substantially on the issue of space heating. The SALDRU data base suggests that more than 80% of all electrified households use electricity for space heating. While this may be representative of long-established electrified or higher income households, lower income households have been found to use other fuels to meet their space heating requirements. This is supported by the consumption study data which indicates much lower levels of fuel use for the purposes of space heating, with many households not dedicating fuel resources to this end-use (this is particularly noticeable in the Durban region, where the warmer climate reduces the need for space heating). Furthermore, a higher usage of coal in Gauteng and paraffin in Cape Town and Port Elizabeth is indicated.
- For the end-use of water heating, the SALDRU (1993) study found that most households use electricity. Other studies have found a strong link between fuels used for cooking and fuels used for water heating. This suggests that there will be wider use of other fuels to meet this end-use.

In *non-electrified* households:

- For the purposes of cooking, it was found that most non-electrified households in all provinces use paraffin. Gas was found to be used in Port Elizabeth, Cape Town and Durban, while in Gauteng, coal was used.
- For the purposes of lighting, a distinctive split exists between regions. Most non-electrified households in Gauteng and Durban use candles, while most non-electrified households in Port Elizabeth and Cape Town use paraffin.
- Paraffin is the main fuel used for space heating in all non-electrified households. In Gauteng, however, coal is more common.
- Paraffin is the main fuel used for water heating in all non-electrified households. Coal is used in Gauteng and gas is used in Durban and Cape Town.

5.2.4 Appliance penetration in user households

This section explores levels of appliance penetration in user households. That is, the most commonly used appliances are identified for the different dwelling categories by fuel type. Appliance ownership is explored as the level of ownership has implications for household energy consumption and the type of appliances used has implications for energy efficiency[6]. The link between appliance ownership and household consumption is, however, not a direct one. It is false to assume that appliance ownership can be equated with appliance use. For example, many households who own electric stoves, may use paraffin stoves predominantly for cooking. Thus it is important to link appliance ownership to fuel end-use and multiple fuel use indicators.

Levels of ownership of appliances vary from area to area and within areas and are influenced by, amongst others, the availability of fuels, the cost of appliances, the methods of financing appliance purchase, household incomes and, in the case of electricity, time-since-connection. Analysis of appliance ownership by area and by dwelling type shows that while there are variations between the areas and between dwelling types, many similarities are also observed. The following section synthesises, by fuel type, the differences and similarities in appliance ownership observed in the areas of Durban, Cape Town, Port Elizabeth and Gauteng and for the different dwelling types. Examples are taken from different areas and presented as representative of household scenarios in South Africa.

[6] The efficiency of appliances is explored in section 5.3.3.

5.2.4.1 *Electrical appliance ownership*

While appliance penetration has some influence on consumption, it is not the primary determinant of electricity demand. Stavrou and May (1993) found that the major factors influencing electricity use were the physical structure and size of the dwelling, time-since-electrification and costs associated with electricity consumption, specifically costs of wiring or extending the wiring of a house, appliance cost and hire purchase (Davis 1995b). Eskom (1994) identify level of urbanisation, income and availability of other fuels as further variables influencing electricity demand. While appliance penetration may not be directly linked to consumption, it can be considered an indicator of levels of consumption. Levels of appliance ownership reflect income levels and other socio-economic variables which, in turn, influence consumption. Knowledge of types of appliances owned is also important to the investigation of end-use and appliance efficiency.

The relationship between appliance penetration in electrified households and socio-economic variables, such as time-since-electrification and income levels needs to be explored. The data analysed does not give any indication of time-since-electrification. Links between income levels and appliance ownership patterns are, however, established and inferences about time-since-electrification can be made. The appliance ownership profiles presented in figures 5.28 and 5.29 reflect differences in household incomes. The Durban example (figure 5.28) refers to formal households with an average monthly income of R1342 and informal households with an average monthly income of R914, while the Cape Town example (figure 5.29) refers to households with an average monthly income of between R300 and R500. It is clear from these examples that household income has an impact on appliance ownership. Figures 5.28 and 5.29 may also be considered representative of variations in time-since-electrification. The Durban example is representative of long-established electrified households, while the Cape Town example is representative of more recently electrified households.

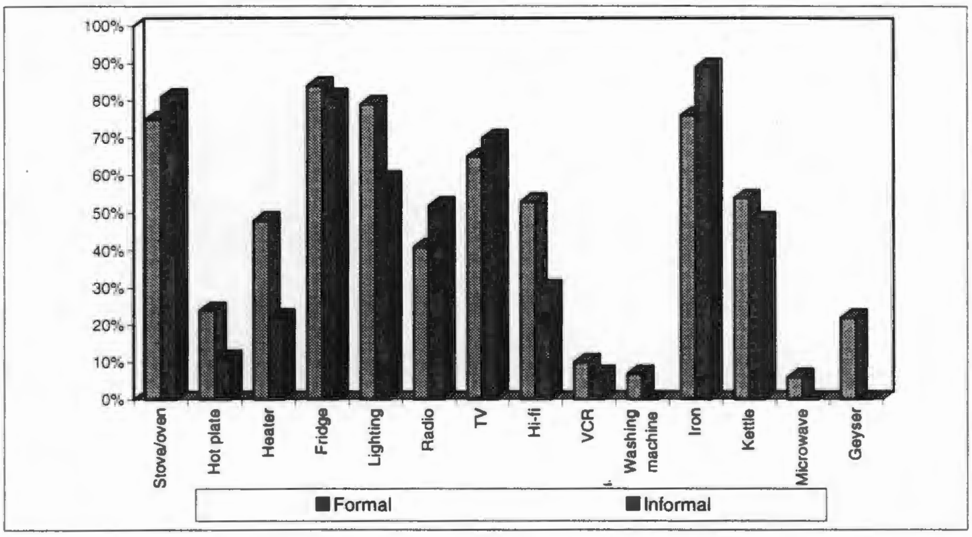

Figure 5.28: Appliance penetration in formal and informal electrified housing in Durban[7]

[7] The informal housing category for Durban includes planned wattle-and-daub type dwellings, many of which have a longer history of access to electricity than the formal dwellings. This accounts for the higher levels of appliance ownership found in informal houses.

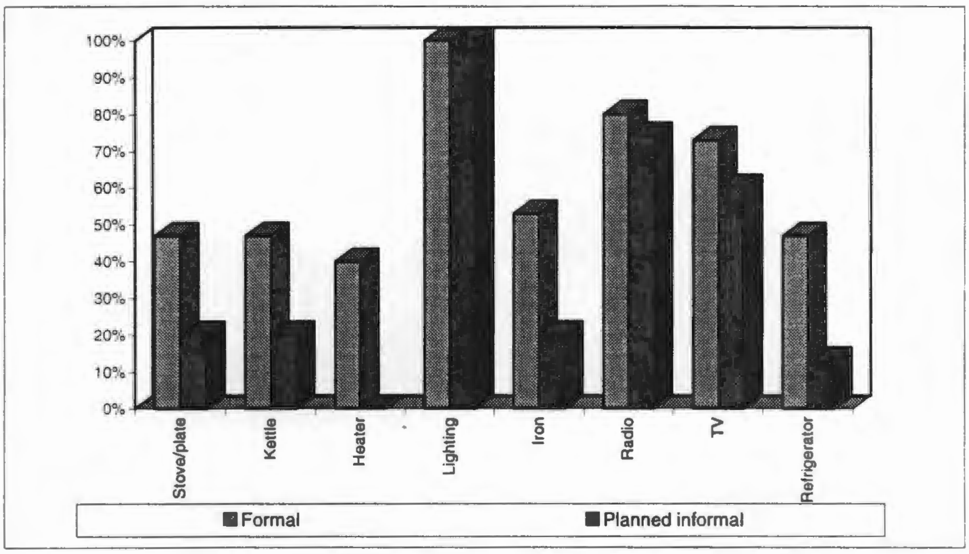

Figure 5.29: Appliance penetration in low-income formal and informal electrified households in Cape Town
Source: Mehlwana & Qase (1996)

In the Durban example (figure 5.28), the sampled households enjoy a full complement of electrical appliances. The most commonly owned appliances were found to be stoves, refrigerators, lights, entertainment appliances (televisions, radios and hi-fis), irons and kettles. There are low levels of penetration of geysers and 'luxury' labour saving devices, such as washing machines and vacuum cleaners. The Durban example can be considered as representative of higher income and long-established electrified households in all urban areas in South Africa. A few significant differences emerge in the other areas. Firstly, the ownership of electric heaters is very low in Durban and is expected to be much higher in the colder areas of the country, for example, Gauteng where between 64% and 70% of formal electrified households have been found to own electric heaters (Williams 1993; Hoets & Golding 1992). Secondly, the ownership of electric stoves is substantially lower in Gauteng, where households persist in using coal stoves after electrification (67% of electrified households in Soweto were found to be using coal stoves) (Williams 1993). Finally, the use of gas in Cape Town, may result in a lower penetration of electric stoves.

In contrast, the Cape Town example (figure 5.29) shows much lower levels of appliance ownership. Electricity is used mainly to power lighting and entertainment appliances. Furthermore, a higher appliance penetration is observed in the formal households than in the more recently electrified informal dwellings. While the Mehlwana & Qase (1996) survey focused on a small selection of household appliances, the data presented in figure 5.29 can be considered as relatively representative of appliance ownership levels in newly electrified households across the country. A survey of electricity demand in newly electrified households conducted by Forlee and Nyikos (1995) in Ivory Park gives an indication of appliance ownership levels for a wider range of appliances.

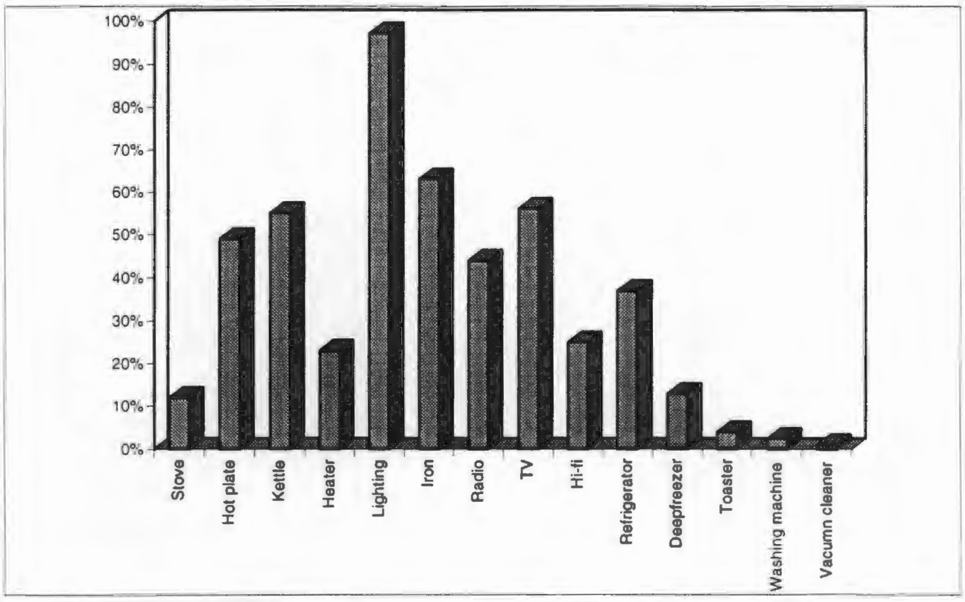

Figure 5.30: Appliance ownership levels of newly electrified households in Ivory Park
Source: Adapted from Forlee & Nyikos (1995)

Figure 5.30 shows levels of appliance ownership in households which have been electrified for approximately three to four years. The sample group displayed the following characteristics:

- an average income of R974.57 and a median income of R800;
- a mean household size of 4.02 and a median household size of 4; and
- an average metered consumption of approximately 120 kWh in June/July 1995 and a median metered consumption ranging between 68.61 kWh in July 1995 and 73.78 kWh in June 1995.

Lighting shows the highest levels of penetration and this can be attributed to the fact that all households were supplied with an electric lightbulb on their readyboard. Ownership levels of electric irons, televisions, kettles, hotplates and radios were also relatively high (more than 40% of all households were found to own these appliances). Furthermore, 51% of all households surveyed were found to own either a refrigerator or a deepfreeze.

Thus, the evidence presented in the Forlee and Nyikos (1995) study of Ivory Park largely supports the work conducted by Mehlwana and Qase (1996) in Cape Town.

5.2.4.2 Paraffin appliance ownership

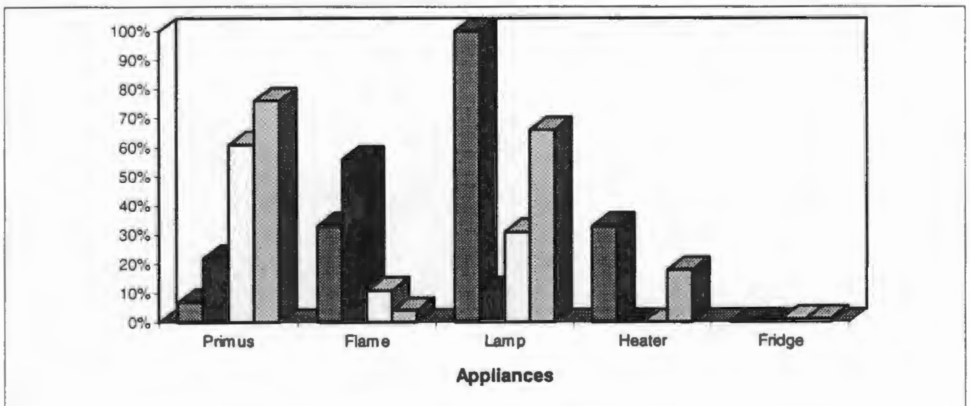

Figure 5.31: Paraffin appliance ownership in formal households in the four focus areas
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mehlwana & Qase (1996)

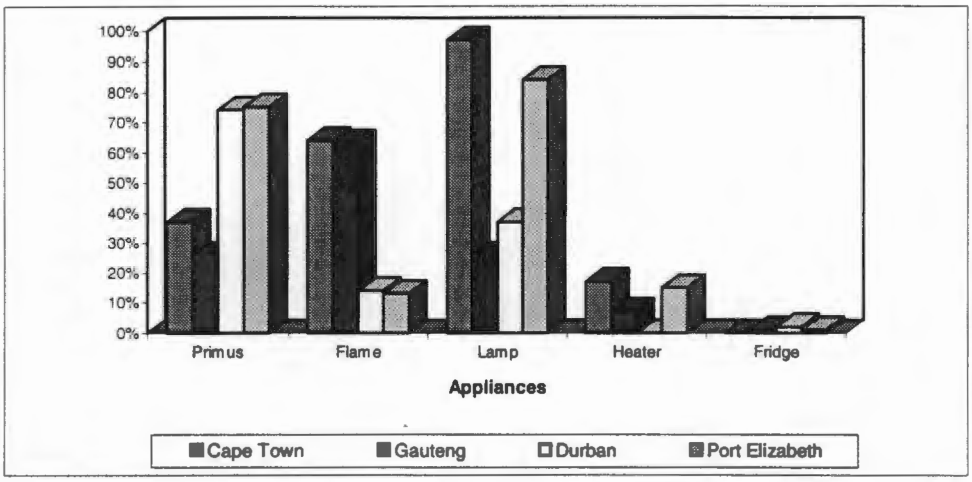

Figure 5.32: Paraffin appliance ownership in informal dwellings in Cape Town, Gauteng, Durban and Port Elizabeth
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993); Mehlwana & Qase (1996)

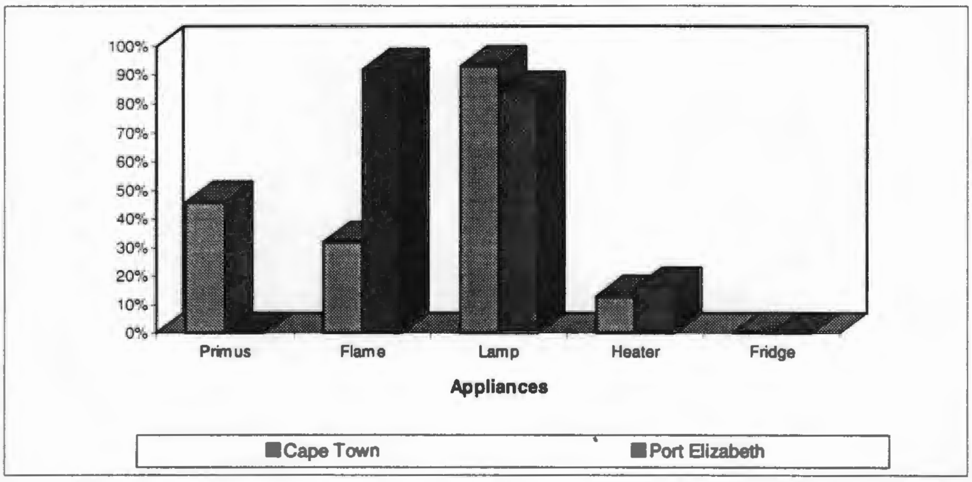

Figure 5.33: Paraffin appliance ownership in backyard shacks in Cape Town and Port Elizabeth
Source: Rossuw & van Wyk (1993); Mehlwana & Qase (1996)

Paraffin appliance ownership varies substantially between areas and is influenced by the cost and availability of paraffin relative to other fuels. Figures 5.31 to 5.33 show the predominance of flame stoves in Cape Town and Gauteng compared with use of primus stoves in Durban and Port Elizabeth. The incidence of paraffin fridge ownership is very low in all areas and in all dwelling types. This can be attributed to the energy consumptiveness and relative cost of operating a paraffin fridge. Very few households own paraffin heaters (less than 35% of households in all areas). No households in Durban were found to own paraffin heaters. This data is supported by Thorne and Theron (1993) who found that 38% of households in Khayelitsha and 59% of households in Langa and Guguletu owned paraffin heaters; Rossouw and van Wyk (1993) who found that 15% of households surveyed in Port Elizabeth owned paraffin heaters; and Gervais (1987) who found that 26% of non-electrified households in Soweto owned paraffin heaters.

Ownership of paraffin lamps varies from area to area, following the end-use trends established in the previous section. Most low-income households in Port Elizabeth and Cape Town own paraffin lamps, while in Durban and Gauteng, only 10% to 40% of households own paraffin lamps. Backyard shacks roughly follow the trends of informal dwellings in each area, although lower levels of ownership of paraffin cooking appliances were found in the backyard shacks surveyed. Furthermore, in Port Elizabeth, flame stoves were found to be more common in backyard shacks, while in formal and planned informal households, primus stoves were found to be more common. In unplanned informal user dwellings in Port Elizabeth, flame stoves also predominated (96% of households surveyed owned flame stoves). This is not evident in figure

5.32 as the sample size for unplanned informal housing was very small (25 households) and most (87%) planned informal user households owned primus stoves.

5.2.4.3 Coal appliance ownership

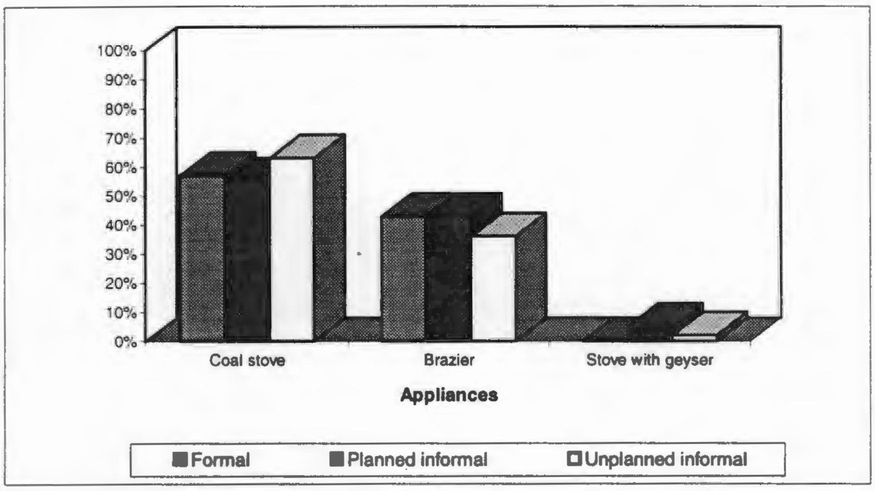

Figure 5.34: Coal appliance ownership in Gauteng
Source: Hoets & Golding (1992)

Figure 5.34 shows that there is a high level of ownership of coal stoves in all dwelling types (between 55% and 65% of households surveyed owned coal stoves). Gervais (1987) found even higher penetrations of coal stoves in Soweto, with 95% of all households and 63% of electrified households using coal stoves. Few coal stoves are fitted with geysers. Those user households who do not own a coal stove, use a brazier as an alternative.

5.2.4.4 Gas appliance ownership

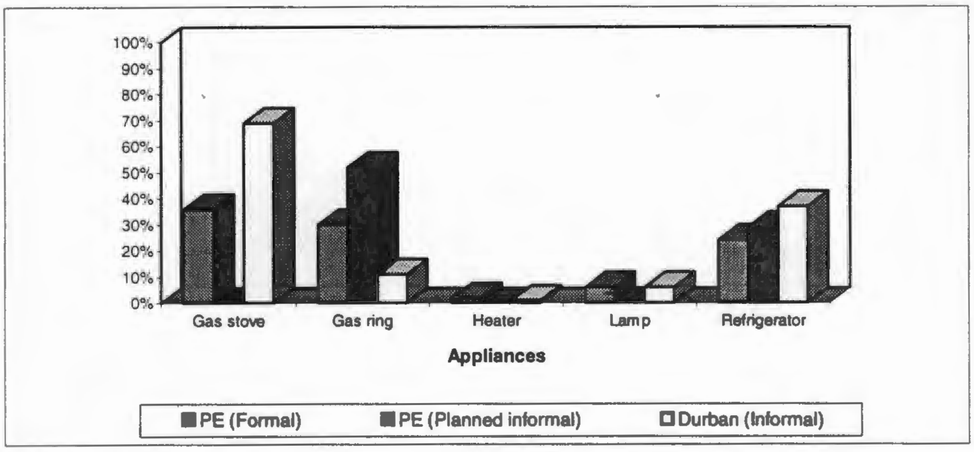

Figure 5.35: Gas appliance ownership in Port Elizabeth and Durban
Source: Hoets & Golding (1992); Rossouw & van Wyk (1993)

There is a moderate level of ownership of gas refrigerators, with non-electrified households using gas as an alternative to electricity for refrigeration. Few gas heaters and lamps were owned. No clear trends exist with regard to the ownership of gas stoves versus gas rings.

5.2.4.5 *Car battery appliance ownership*

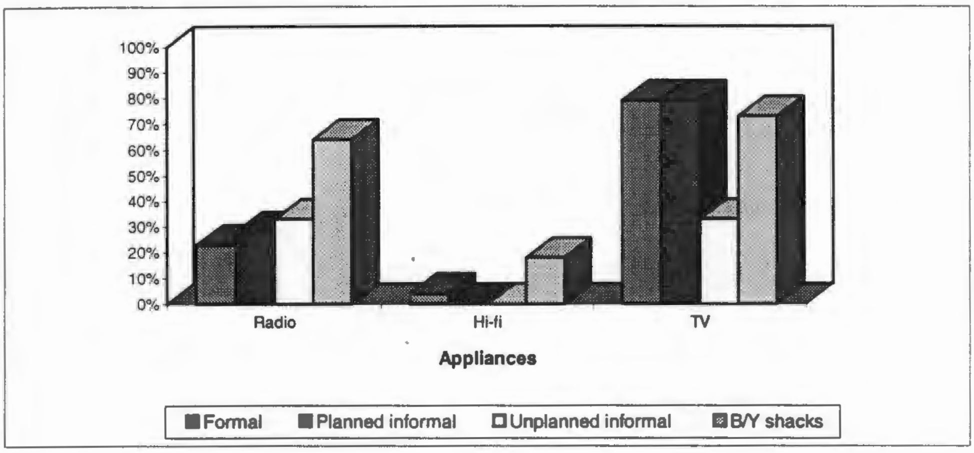

Figure 5.36: Appliances powered by car batteries in Port Elizabeth
Source: Rossouw & van Wyk (1993)

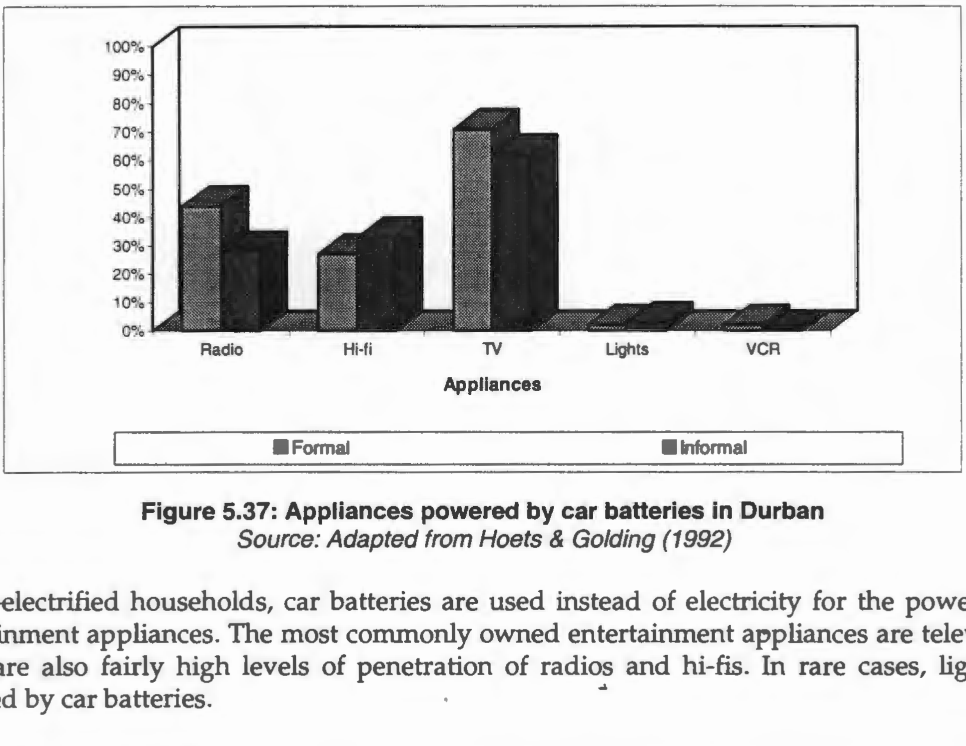

Figure 5.37: Appliances powered by car batteries in Durban
Source: Adapted from Hoets & Golding (1992)

In non-electrified households, car batteries are used instead of electricity for the powering of entertainment appliances. The most commonly owned entertainment appliances are televisions. There are also fairly high levels of penetration of radios and hi-fis. In rare cases, lights are powered by car batteries.

5.2.5 Fuel preferences

While the efficiency of the different fuels to meet certain needs is an essential criterion by which to judge the appropriateness of different fuels, it is vital that one does not discount household attitudes toward and preference for different fuels. The consumption studies for the selected areas, together with the social determinants studies, indicate household fuel preferences and the influence that attitudes have on fuel choice. When making decisions about substitution of more efficient fuels for less efficient fuels, one must ensure that the fuels are appropriate for the specific end-use (for example, not just substituting one fuel for cooking with another, but taking into account the type of meal cooked) and are comparable in terms of cost of both fuel and appliances needed to perform the task. Furthermore, it is necessary to have an understanding of the social determinants influencing fuel choice.

Electricity is generally found to be the most desired fuel. In Port Elizabeth a strong preference for electricity was expressed, while paraffin, gas and generators were cited as the next most preferred fuels. The major advantages of electricity were perceived to be its versatility in meeting a full range of end-uses and the fact that it is perceived as a clean fuel. The cost of electric appliances was cited as a major deterrent to the use of electricity. Affordability of the fuel was an important factor in the expression of preferences. Those who expressed a preference for coal and wood, cited their ability to produce warmth while meeting other needs as the primary reason. Paraffin and vehicle batteries were preferred for their affordability and ready availability. Paraffin, wood and coal were, however, cited as being dirty and producing smoke and bad odours. Gas was cited as a cleaner fuel, but was perceived to be dangerous (Rossouw & van Wyk 1993).

In Gauteng, paraffin and candles were cited as being the least liked fuels. The reasons for this being that they are dangerous, smoky, inconvenient and expensive. Coal and gas were also cited as being disliked. Coal was, however, cited for its versatility (that is, its dual function of meeting both cooking and space heating end-uses) and gas for its efficiency and cleanliness. Gas was, however, viewed as costly and dangerous (Hoets & Golding 1992).

In Durban, paraffin and candles were again cited as being the least liked fuels due to their inconvenience, danger, polluting quality and cost. Owing to its unreliability and to its cost, electricity was also cited as a less preferred fuel. The area surveyed was subject to fluctuations in electricity supply and frequent power cuts. It can be expected that if the electricity supply were more reliable, electricity would be a preferred fuel in Durban, as it is in the other urban areas. Gas was viewed as being clean, but costly and dangerous (Hoets & Golding 1992). Jones et al's (1996) survey supports this finding. They found a preference for paraffin over gas in low-income households in Durban, which was attributed to the facts that paraffin was more readily available than gas; could be bought in small, more affordable quantities; required a smaller capital outlay; and was perceived as being easier to control as it is more tangible than gas.

It is important to note the divergence between expressed preferences and practice. For example, while a strong preference for electricity was expressed, many households continue to use other fuels after electrification. A number of reasons have been identified to explain the gap between preference and practice. These include:

- cost;
- social relations of fuel use; and
- fear of the unknown.

The cost of both fuels and appliances is a major factor influencing fuel use. Where households express a preference for one fuel over another, the switching between fuels is often inhibited by the cost of purchasing appliances. Furthermore, the way in which fuels are purchased is also an important factor. Paraffin is often purchased in small quantities from the local spazas and can be purchased at any time, when required. Gas is purchased in larger quantities and is predominantly purchased from larger retail outlets during normal business hours. Electricity can be purchased in small quantities if using a prepayment metre, but again electricity can only be purchased during set times. Thus, if households run out of fuel, they have to wait until the shops are open to purchase more. For households with erratic incomes, being able to buy fuel in small quantities when required is an essential survival strategy.

Another significant factor influencing the continued use of paraffin is the way in which paraffin circulates within communities. Jones et al (1996) and Mehlwana and Qase (1996) found paraffin-sharing in low-income communities to be an important factor influencing the choice of fuel. Fuel can be borrowed from neighbours when the need arises. It was also found that paraffin can be bought on credit from the local spazas in Cape Town and Gauteng. These are both important survival strategies in low-income households and influence fuel use.

Households are familiar with using a particular fuel, often paraffin, and while they may perceive benefits of switching to another fuel, for example gas or electricity, their lack of knowledge surrounding budgeting for and using the fuel often inhibits their transition from paraffin to electricity or gas.

5.3 Fuel data

This section presents the fuel data required to calculate end-use energy consumption. The data below gives the calorific values of fuels used in low-income households, the prices of those fuels in the different metropolitan areas and the efficiencies and efficacies of different appliances/fuel combinations.

5.3.1 Energy content by fuel type

In order to draw conclusions around household energy consumption, it is necessary to be able to compare the different fuels in terms of their energy content.[8] Table 5.1 below indicates the calorific values of the range of fuels commonly used in low-income households in South Africa.

Fuel	*Unit*	*Energy content*	
		MJ	*kWh*[9]
Electricity	kWh	3.6	1
LPG	kg	49	13.6
Paraffin	l	37	10.3
Dry wood	kg	17	4.7
Coal[10]	kg	27	7.5
Car batteries	charge	1.3	0.36
PM-9 battery	each	0.081	0.02
PM-10 battery	each	0.020	0.006
Candles	each	3.45	0.96

Table 5.1: Calorific values of range of fuels
Source:Thorne (1995); Davis & Horvei (1995)

The values presented in table 5.1 are average calorific values for any given fuel. Variations in heating values are found particularly in solids and can be attributed to differences in water, ash and volatile content. Liquid fuels have a much more uniform energy content but there are still some differences due to refinery specifications and blending. The moisture content of wood has a significant impact on its heating value. Davis and Horvei (1995) estimate that the calorific value of wood ranges between 10.9 (with a moisture content of 40%) and 15.5 (with a moisture content of 20%) MJ/kilogram. Moisture content varies according to several factors, which include the species, atmospheric humidity (climate and seasonal factors), drying time and hence drying conditions (temperature and ventilation) (Leach & Gowen 1987).

5.3.2 Price of fuels

The price of fuels for the different areas has been gathered from a wide variety of sources and is presented in table 5.2 below.

8 *Energy content/heating value* measures the quantity of energy in a fuel per unit weight or volume (for example, MJ/kg) (Leach & Gowen 1987).

9 The conversion factor from MJ to kWh is 0.278, i.e. 3.6MJ = 1kWh.

10 The value for coal refers to `Grade C nuts`, the coal most commonly used in South African low-income households.

Fuel type	*Price by area*			
	Johannesburg[11]	*Port Elizabeth*[12]	*Durban*[13]	*Cape Town*[14]
Electricity (R/kWh)	0.1949 - 0.2684	0.2005 - 0.2684	0.24165 - 0.2684	0.2286 - 0.2684
Candles				
Loose candles	50c	*	48-54c	35-65c
Packet	R2.52	*	*	*
Paraffin (R/litre)	1.67	1.48-2.02	1.40-1.66	1.04-1.50
Coal (R/kg)	0.23	*	*	0.50-0.55
Gas (R/kg)	3.78	3.60-4.89	2.45-3.15	1.66-3.66
Dry batteries (R)				
PM9	7.68	*	*	6.99
PM10	10.92	*	*	*
Car batteries per charge for 12 volt battery	5.29	5.00	4.65-6.26	5.00
Wood (kg)	*	*	1.27-1.46	0.43-0.45

Table 5.2: Prices of fuels used by low-income households in Port Elizabeth, Cape Town, Gauteng and Durban

5.3.3 Fuel efficiencies and efficacies

'Efficiencies are defined as the ratio of useful energy to gross energy when using a particular appliance. Efficacies are generally used for lighting where it is difficult to define the useful energy output' (Davis & Horvei 1995: 6.21). The efficacy of a lamp is defined as the ratio of lumen output to the power consumption of the lamp.

In order to calculate the useful energy consumption, it is necessary to multiply the gross or delivered energy consumption by appliance efficiency. Table 5.3 below presents efficiencies and efficacies for a range of different appliance/fuel combinations.

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11 The electricity price quoted by the Eastern Metropolitan Substructure in July 1996 was 19.49c/kWh, while Eskom's electricity charge was 26.84c/kWh for Homelight 1 customers. The fuel prices for all fuels, other than electricity, are draft figures for a study being completed by the Palmer Development Group in Kameelrivier B, an area about 160km north-east of Pretoria.

12 The electricity price quoted by the Port Elizabeth municipality in July 1996 was 20.05c/kWh. Eskom's electricity charge for Homelight 1 customers was 26.84c/kWh. Paraffin, LPG and car battery prices are taken from the East London study of Duncan Village (1996). A price differential of 0.01 is used to correct for price differences between East London and Port Elizabeth (Port Elizabeth's prices were cited as being, on average, 1% higher than prices in East London in the 1995 Consumer Price Index (CPI)).

13 Electricity prices were quoted as being 24.165c/kWh by the Durban Muncipality in July 1996. Eskom's Homelight 1 tariff was 26.84c/kWh. The unit costs of fuel, with the exception of electricity, were taken from the Hoets and Golding (1992) study and updated to 1995 levels, using the consumer price indices (CPI) of 8.6% for 1993, 8.86% for 1994 and 8.78% for 1995 (until May 1995) (CSS 1995).

14 Paraffin, LPG, vehicle battery, dry battery and candle prices are taken from Mehlwana & Qase (1996). Coal and wood prices are taken from *Cape Coal (pty) Ltd* (1996). The price ranges for coal and wood are based on collected versus delivered prices. Coal is sold in 40kg bags for between R20.00 and R22.00, while wood is sold in 20kg bags for between R8.50 and R9.00. The electricity price was quoted as being 22.86c/kWh in July 1996 by the Cape Town Municipality. Eskom's Homelight 1 tariff was 26.84c/kWh.

End-use	Fuel	Appliance	Min	Max	Ave
Cooking	Electricity	Stove	55%	75%	65%
		Hot plate	55%	75%	65%
	Paraffin	Wick	20%	35%	30%
		Primus	30%	55%	40%
	Gas	Ring	40%	60%	45%
		Stove	40%	60%	45%
	Wood	3-stone	13%	15%	15%
		Stove	20%	30%	25%
	Coal	Stove	20%	30%	25%
		Brazier	6%	10%	8%
Water heating	Electricity	Geyser	48%	92%	58%
		On-line	96%	96%	96%
	Paraffin	Wick/pot	20%	35%	30%
		Primus/pot	30%	55%	40%
	Gas	Ring/pot	40%	60%	45%
		Geyser	75%	92%	80%
	Wood	File/pot	13%	15%	14%
		Stove/pot	20%	30%	25%
	Coal	Stove	20%	46%	30%
Space heating	Electricity	Radiant	100%	100%	100%
	Paraffin	Heater	45%	100%	72.5%
		Primus	45%	100%	*
	Gas	Heater	40%	100%	70%
		Ring stove	40%	100%	*
	Wood	Open fire	85%	100%	92.5%
		Stove	20%	60%	40%
	Coal	Stove	20%	60%	*
		Brazier	17%	17%	17%
Lighting	Electricity	60W incandescent	11 lumens/Watt		
		100W incandescent	18 lumens/Watt		
		20W fluorescent	62 lumens/Watt		
		40W fluorescent	75 lumens/Watt		
	Candle		0.2 lumens/Watt		
	Paraffin	Wick lamp	0.3 lumens/Watt		
		Pressure lamp	1.2 lumens/Watt		
	Gas	Gas lamp	1 lumens/Watt		

Table 5.3: Efficiencies and efficacies of a range of appliance/fuel combinations
Source: Thome (1995); Davis & Horvei (1995)

5.3.4 Breakdown of end-use consumption

Data on energy consumption is presented in terms of total monthly consumption per individual household. In order to calculate end-use consumption, it is necessary to determine the proportion of the fuel bill that is dedicated to the different end-uses. This varies according to the efficiency of the fuel type, climate, the functions that the fuel can perform and household practises.

Leach and Gowen (1987) found that among the poorest households in developing countries, cooking and heating (both space and water) account for 90 to 100% of fuel consumption. The remainder of household fuel use was attributed to lighting needs. In South Africa, low-income households reflect these observations. The major end-uses are cooking, heating and lighting. The range of needs for which households use energy is, however, influenced by the type of fuel used and climate. Low-income electrified households, for example, frequently use energy for entertainment services and, to a lesser degree, refrigeration. Furthermore, space heating requirements vary substantially between regions and are influenced by the variable of climate.

This link between space heating and climate is supported by Leach and Gowen (1987). They found that in Kenya, cooking and water heating end-uses accounted for between 79% and 92% of fuel use, while space heating varied between 4% in the warmer regions and 20% in the cooler regions of Kenya (CBS 1980 cited in Leach & Gowen 1987). Further, they found substantial variations in fuel dedicated to space heating in the warmer country of India and the cooler country of Chile. In India, fuel dedicated to space heating was found to be negligible and household fuel consumption was divided between the end-uses of cooking, water heating and lighting. These breakdowns are presented in table 5.4 below.

End-uses	*India (Reddy et al 1980)*	*Chile (Diaz & de Valle 1984)*
Cooking	76-81%	42-55%
Water heating	14-19%	14-22%
Space heating	*	23-52%
Lighting	2-3%	*

Table 5.4: Break down of household fuel consumption by end-use in India and Chile
Source: Cited in Leach & Gowen (1987)

Table 5.5 below shows the breakdown of fuel consumption in terms of a limited range of end-uses commonly performed in low-income households in South Africa.

	Electricity	*Paraffin*	*Gas*	*Coal/wood*
Cooking	15-35%	25-35%	75-85%	40-50%
Space heating	15-20%	25-35%	*	40-50%
Water heating	35-45%	10-20%	15-25%	10-20%
Lighting	5%	20-30%	*	*
Refrigeration	5-10%	*	*	*
Media	3%	*	*	*

Table 5.5: Percentage breakdown of fuel use by end-use in South Africa
Source: Berrisford (1993); Thorne (1995)

The proportion of the fuel bill dedicated to the different end-uses is dependent on the range of activities performed in the household. For example in electrified households which use a full range of electrical appliances, cooking and water heating together account for between 60% and 70% of monthly electricity consumption. The rest of the electricity bill is divided between the end-uses of space heating, lighting, refrigeration and media (approximately 15% to 20%, 5%, 6% and 3% respectively). For households without geysers, between 30% and 35% of monthly electricity consumption is dedicated to cooking. Households use appliances very differently. The use of appliances is influenced by levels of income and perceptions and knowledge of the energy intensity of appliances. Thus, the above estimates must be considered as averages and may not reflect individual household breakdown of energy use. Where households use paraffin or gas refrigerators, a large proportion of the fuel bill will be dedicated to the end-use of refrigeration (approximately 60% of the fuel bill). Few households own paraffin or gas refrigerators due to their high energy consumption and, therefore, these have been omitted from the breakdowns. The section below further investigates the breakdown of household energy consumption by end-use.

5.4 End-use data

All use of fuels involves a series of energy conversions. These conversions usually change the physical nature of the fuel, or the form of energy, in order to increase its utility. Invariably some energy is lost to the environment during these conversion processes. This concept is basic to energy measurement and to such important factors as the *energy content of fuels* and the *efficiency of conversion processes*. The energy content of fuels is measured at three different states in the conversion process. These measurements, termed primary, secondary/delivered and utilised energy, are detailed below.

- *Primary energy* is the potential energy content of the fuel in the form in which it is extracted, discovered or produced (prior to any conversion processes).
- *Secondary/delivered energy* is the potential energy content of the fuel once it has been converted for use (primary energy minus the amount of energy used and lost in supply-side conversion systems). This is the energy purchased by the household and includes marketing and distribution losses.
- *Utilised/useful energy* is the energy used for cooking, heating etc. That is, it measures the amount of work or heat used to accomplish a specific task or service (delivered energy minus energy wasted in the cooking, heating process). The difference between delivered and utilised energy varies substantially according to the type of fuel and the conversion technology used (Leach & Gowen 1987).

This section presents energy consumption for typical households in South Africa in terms of monthly cost and delivered and useful energy.

5.4.1 Household consumption by fuel type

The following section presents total monthly household consumption by fuel type. For each fuel type, the range of end-uses is identified as well as the variations across the country. This information is informed by observations of fuel use recorded in section 5.2.

5.4.1.1 Electricity consumption

Electricity consumption varies substantially between households. As mentioned in section 5.2.4.1, monthly household consumption of electricity is influenced by income, time-since-electrification and the related variable of appliance ownership. Appliance penetration is, however, not a direct indicator of household consumption. Consumption varies according to the use of appliances which is, in turn, influenced by income. The following scenarios are evaluated:

- a newly electrified household with limited appliance ownership and use; and
- a developed low-income household with a long history of electricity use.

5.4.1.1.1 Newly electrified households

Davis and Horvei (1995) correlate consumption and time-since-connection for prepayment-metered customers, showing the growth in household electricity consumption for newly electrified households over time on a regional basis (see table 5.6).

Average monthly household energy consumption after connection (kWh)[15]					
	1 month	*12 months*	*24 months*	*36 months*	*48 months*
Cape Town	60	80	105	135	155
Durban	25	45	60	75	100
Johannesburg	60	70	75	80	90

Table 5.6: Electricity consumption (kWh) in newly electrified households
Source: Davis & Horvei (1995)

[15] Based on consumption for March, April and May 1994.

On a national level, Davis (1995) found monthly consumption levels for newly electrified households to be in the region of 80 to 150kWh per customer. Work conducted by Forlee and Nyikos (1995) and Probert (1992) on newly electrified households confirm these findings.

Forlee and Nyikos (1995) investigated household electricity demand in the newly electrified community of Ivory Park. They found that households who have been electrified for between three to four years consume, on average, approximately 120.5kWh per month or a median consumption level of between 68.61kWh and 73.78kWh per month. The most commonly owned appliances in these households were:

- lighting (96.6%),
- iron (62.5%),
- television (55.9%),
- kettle (55%),
- hotplate (49.1%), and
- radio (43.8%).

Similarly, Probert (1992) estimated that a newly electrified settlement with the following appliance penetrations,

- lighting (100%),
- iron (50%),
- kettle (80%),
- television (80%), and
- hotplate (100%)

would have an average monthly household consumption of 136kWh.

Examination of consumption per end-use showed the following contributions of each appliance.

	Forlee & Nyikos (1995)		*Probert (1992)*	
	kWh/month	*%*	*kWh/month*	*%*
Lights	17.15	15	48.21	35
Iron	2.75	3	12.38	10
Television	12.16*	11	12.16	9
Kettle	16.39	14	21.21	15
Hotplate	53.91	47	45.02	32
Radio	11.92*	10		
Total consumption	**114.28**	**100**	**138.98**	**100**

* Values taken from Probert (1992)

Table 5.7: Breakdown of energy consumption by end-use in newly electrified households (expressed in kWh/month)

End-uses	*Quantity*		*Unit cost*	*Monthly cost*		*Delivered energy (MJ)*		*Efficiency*		*Useful energy (MJ)*	
	Min	*Max*		*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Best*	*Worst*
Lighting	17.15	48.21	0.2684	4.60	12.94	61.8	173.6	*	*	*	*
Ironing	2.75	12.38	0.2684	0.74	3.32	9.9	44.6	*	*	*	*
Entertainment	12.16	24.08	0.2684	3.26	6.46	43.8	86.7	*	*	*	*
Kettle	16.39	21.21	0.2684	4.40	5.69	59.0	76.4	*	*	*	*
Hotplate	45.02	53.91	0.2684	12.08	14.47	162.1	194.1	55%	75%	121.6	106.8

Table 5.8: Monthly household electricity consumption in newly electrified households

Table 5.8 above presents a range of quantity and cost values for the most common electrical end-uses in newly-electrified households. It is estimated that newly electrified households using electricity for lighting, ironing, entertainment, cooking and some water heating, consume between 93.47 and 159.97 kWh per month at an average monthly cost of R25.08 and R42.88 respectively. Cooking contributes the most to the households monthly electricity consumption, with lighting being the second largest contributor.

5.4.1.1.2 Established electrified households

The consumption profiles for electrified households presented in the SALDRU (1993), Hoets and Golding (1992) and Rossouw and van Wyk (1993) studies are representative of long-established low-income electrified households. Table 5.9 below shows the variations in measured electricity consumption for long-established electrified households.

Area	*SALDRU (1993)*	*Consumption studies*	
		Formal	*Planned informal*
Cape Town	554	139	92
PE	380	211	265
Durban	505-561	518	340
Gauteng	512	255	198

Table 5.9: Electricity consumption (kWh) by region and dwelling type
Source: SALDRU (1993); Hoets & Golding (1992); Rossouw & van Wyk (1993); Mehlwana & Qase (1996)

The SALDRU (1993) study found that electricity consumption ranged between 380kWh per month in Port Elizabeth and 561kWh per month in Durban, with most households consuming between 500 and 560kWh per month. Rossouw and van Wyk (1993) found electricity consumption to range between 211 and 265 kWh in Port Elizabeth, and Hoets and Golding (1992) found electricity consumption to range between 198 and 255kWh per month in Gauteng and between 340 and 518kWh per month in Durban. It is important to note that while regional variations in electricity consumption are observed in table 5.8, much rests on the type of settlement selected and the related variables of income, household size and length of time established. Substantial variations within regions are observed as well. For example, Berrisford (1993) found an average consumption of 394kWh in Khayelitsha in Cape Town, an average consumption of 413kWh in Umlazi in Durban and an average monthly consumption of 1280kWh in Soweto in Gauteng. In Naledi extension 2, a newer part of Soweto, much lower levels of consumption were observed (493kWh).

For long established electrified households, it is assumed that households consume between 350kWh and 560kWh per month. The lower limit of 350kWh is set in accordance with the individual customer demand required to make the current electrification drive economically viable (Probert 1992). The upper limit of 560kWh is set by the findings of the SALDRU (1993) survey. Data on appliance penetrations in formal and informal dwellings in Durban were taken as representative of the upper and lower limits of long-established electrified households. These appliance penetrations are presented in table 5.10 below.

	Formal households 560kWh	*Informal households 350kWh*
Stove/oven	75%	81%
Heater	48%	*
Fridge	84%	81%
Lighting	79%	59%
Radio	41%	52%
TV	65%	70%
Hi-fi	53%	*
Iron	76%	89%
Kettle	54%	48%

Table 5.10: Appliance penetrations in formal and informal households in Durban
Source: Hoets & Golding (1992)

Table 5.11 below shows the contribution of each appliance to monthly household electricity consumption for long-established electrified households.

	High consumption levels		Low consumption levels	
	kWh	%	kWh	%
Stove/oven	221.5	39	140.86	41
Heater	130	23	0	0
Fridge	90	16	90	26
Lighting	42	8	42	12
Radio	2.2	0.4	2.2	0.6
TV	14.4	3	14.4	4
Hi-fi	5.4	1	0	0
Iron	24.0	4	24.0	7
Kettle	32.4	6	32.4	9
	561.90	100	345.86	100

Table 5.11: Breakdown of energy consumption by end-use in established electrified households
Source: Electrowise (1995); Probert (1992)

End-uses	Quantity		Unit cost	Monthly cost		Delivered energy (MJ)		Efficiency		Useful energy (MJ)	
	Min	Max		Min	Max	Min	Max	Min	Max	Best	Worst
Lighting	42.0	42.0	0.2684	11.27	11.27	151.2	151.2	*	*	*	*
Ironing	24.0	24.0	0.2684	6.44	6.44	86.4	86.4	*	*	*	*
Entertainment	16.6	22.0	0.2684	4.46	5.9	59.8	79.2	*	*	*	*
Kettle	32.4	32.4	0.2684	8.70	8.70	116.6	116.6	*	*	*	*
Space heating	0	130	0.2684	0	34.89	0	468	100%	100%	468	468
Refrigeration	90	90	0.2684	24.16	24.16	324	324	*	*	*	*
Cooking	140.86	221.5	0.2684	37.81	59.45	507.1	797.4	55%	75%	380.3	438.6

Table 5.12: Monthly household electricity consumption in established electrified households

For long established low-income electrified households using electricity for lighting, ironing, entertainment, refrigeration, cooking, and water and space heating, it was found that households consume between 345.86 and 561.90 kWh per month at an average monthly cost of between R92.84 and R150.81. Cooking, space heating and refrigeration were found to be the largest contributors to household energy consumption. Electrical energy consumed for the purposes of water heating is underestimated as only the use of kettles is represented in table 5.12. In houses without geysers, water is also heated on electrical stoves and thus a share of the electrical energy consumed used for cooking may be attributed to water heating.

5.4.1.2 Paraffin consumption

Paraffin consumption varies between electrified and non-electrified households and between areas. Electrified households were found to use between 20% and 30% less paraffin than non-electrified households and households in Gauteng were found to use approximately two-thirds of the amount of paraffin as households in Cape Town.

Area	Electrification		Dwelling type			
	Electrified	Not elec.	Formal	Planned informal	Unplanned informal	Backyard shacks
Cape Town	29	53	36	39	37	27.5
PE	13-17	22-30	16-22	14-19	15-20	12-16
Durban	10	28	31	36	36	*
Gauteng	14	21	25	26	25	*

Table 5.13: Paraffin consumption (litres) per month by access to electricity and dwelling type

As electrified households and households in Gauteng use less paraffin for lighting than non-electrified households in Port Elizabeth and Cape Town, it can be assumed that approximately half the difference between the different categories is attributed to lighting. Thus, it is argued that between 10% and 20% of paraffin consumption can be attributed to lighting. Basing the breakdown on Leach and Gowen (1987), it is estimated that the remainder of the monthly paraffin consumption can be split as follows:

- 35% for space heating;
- 45% for cooking; and
- 20% for water heating.

Taking Cape Town as representative of households consuming paraffin for cooking, space heating, water heating and lighting, table 5.14 shows the breakdown of paraffin use in low-income households. It was approximated that low-income households use between 35 and 55 litres of paraffin per month at an average cost of R45.50 and R71.30 respectively.

End-uses	Quantity		Unit cost	Monthly cost		Delivered energy (MJ)		Efficiency		Useful energy (MJ)	
	Min	Max		Min	Max	Min	Max	Min	Max	Best	Worst
Cooking	13.5	21	1.30	17.55	27.30	499.5	777	30%	55%	274.7	233.1
Space heating	10.5	16.3	1.30	13.65	21.19	388.5	603	45%	100%	388.5	271.4
Water heating	6	9.3	1.30	7.80	12.09	222	344	30%	55%	122.1	103.2
Lighting	5	8.4	1.30	6.50	8.45	185	311	*	*	*	*

Table 5.14: Monthly paraffin consumption

5.4.1.3 Gas consumption

Gas consumption varies widely between electrified and non-electrified households and between areas. The regional variations in gas consumption are presented in table 5.15 below.

Area	Electrification		Dwelling type			
	Electrified	Not elec.	Formal	Planned informal	Unplanned informal	Backyard shacks
Cape Town	15	21-29	25	29	16.3	11.8
PE	6-8	15-20	12-16	9-12	8.5-11.5	8-11
Durban	10	17	20	23	23	*
Gauteng	6	14	12	*	12	*

Table 5.15: Gas consumption (kilograms) by access-to electricity and dwelling type

Non-electrified households were found to use between 40% and 60% more gas per month than electrified households. Furthermore, gas is more commonly used in Cape Town, Port Elizabeth and Durban than in Gauteng. Cape Town is taken as representative of gas users. Few households were found to use gas for space heating and, therefore, only cooking and water heating end-uses are considered. Basing the breakdown on Leach and Gowen (1987), it is estimated that monthly gas consumption can be split as follows:

- 75% to 85% of monthly gas consumption is dedicated to cooking; and
- 15% to 25% of monthly gas consumption is dedicated to water heating.

Gas consumption by end-use is presented in table 5.16 below.

End-uses	Quantity		Unit cost	Monthly cost		Delivered energy (MJ)		Efficiency		Useful energy (MJ)	
	Min	Max		Min	Max	Min	Max	Min	Max	Best	Worst
Cooking	12	24	2.50	30.00	60.00	588	1176	40%	60%	352.8	470.4
Water heating[16]	3	6	2.50	7.50	15.00	147	294	40%	60%	88.2	117.6

Table 5.16: Monthly household gas consumption

Table 5.16 shows that households in Cape Town consuming between 15 and 30 kilograms of gas per month incur an average monthly cost of between R37.50 and R 75.00.

5.4.1.4 Coal consumption

Area	Electrification		Dwelling type		
	Electrified	Not elec.	Formal	Planned informal	Unplanned informal
Gauteng	177	229	146	210	190

Table 5.17: Coal consumption (kilograms) by access to electricity and dwelling type

When evaluating coal consumption, it is important to note the strong seasonal variations in coal use, with winter consumption being approximately double that of summer consumption. The Palmer Development Group (1995) extrapolate from a number of different sources (Louis Heyl & Associates 1987; Hoets & Golding 1992; Hoets 1994; Palmer Development Group 1995) to obtain an average consumption figure for low-income households in the Gauteng region. They found that households using coal stoves consume, on average, 175kg per month in the summer months and 413 kilograms per month in the winter months. The figures derived from the PSLSD and Hoets and Golding (1992) and presented in table 5.17, appear to be representative of summer consumption levels. It can be concluded that a household using coal to meet all three possible end-uses will consume, on average, 413kg per month. While the difference between summer and winter consumption can largely be attributed to space heating, some of the variation is a result of households switching from coal to paraffin for cooking in summer, a common practice in Gauteng, where households attempt to reduce the space heating effects of cooking with coal by increasing their use of paraffin as an alternative.

Using a breakdown of coal use by end-use of 40% to 50% of coal is used for cooking, 40% to 50% of coal is used for space heating and 10% to 20% is used for water heating, it is calculated that coal-using households consume between 165 and 207 kilograms of coal per month for cooking, between 165 and 207 kilograms of coal per month for space heating, and between 41 and 83 kilograms of coal per month for water heating. If it is assumed that 50% of coal consumption can be attributed to space heating, then households using coal for cooking and water heating in summer, consume approximately 206kg of coal. This approximates the consumption figures presented in the SALDRU (1993) and Hoets and Golding (1992) surveys which found that non-electrified households[17] use between 190 and 229 kilograms of coal per month.

Table 5.18 below shows monthly household consumption in terms of units consumed, delivered energy (MJ), monthly expenditure and useful energy.

16 Few low-income households in South Africa own geysers fueled by gas and, therefore, the efficiency values for water heating are for gas ring appliances.

17 In the case of the Hoets and Golding (1992) survey, non-electrified is equated with informal dwellings as few of these dwellings are electrified.

End-uses	Quantity		Unit cost	Monthly cost		Delivered energy (MJ)		Efficiency		Useful energy (MJ)	
	Min	Max		Min	Max	Min	Max	Min	Max	Best	Worst
Cooking	165	207	0.23	37.95	47.61	4 455	5 589	20%	30%	1 337	1 118
Space heating	165	207	0.23	37.95	47.61	4 455	5 589	20%	60%	2 673	1 118
Water heating	41	83	0.23	9.43	19.09	1 107	2 241	20%	46%	509	448

Table 5.18: Monthly household coal consumption for users of coal stoves

5.4.1.5 Candle consumption

Candle consumption varies between areas and between electrified and non-electrified households. As shown in section 5.2, use of candles for lighting is greatest in Durban and Gauteng. In Cape Town and Port Elizabeth, households predominantly use paraffin for lighting, although some non-electrified households use a combination of paraffin and candles.

Area	Electrification		Dwelling type			
	Electrified	Not elec.	Formal	Planned informal	Unplanned informal	Backyard shacks
Cape Town	19	28-35	*	15	*	*
PE	21	19	12	13	16	24
Durban	12	36	37	37	37	*
Gauteng	11	22	31	34	35	*

Table 5.19: Candle consumption (candles) by access to electricity and dwelling type

Data compiled by Hoets and Golding (1992) on non-electrified households in Durban and Gauteng (informal households) is considered as representative of households using candles only for lighting. Data compiled by SALDRU (1993) on electrified households in Durban and Gauteng is considered representative of households using both electricity and candles for lighting. SALDRU (1993) data for Cape Town and Port Elizabeth shows fairly high usage of candles in these areas. Evidence presented by Mehlwana and Qase (1996) and Rossouw and van Wyk (1993) is taken as representative of households using both paraffin and candles for lighting.

Thus it is concluded that:

- non-electrified households using candles only, consume between 34 and 37 candles per month;[18]
- electrified households using candles and electricity, consume between 11 and 12 candles per month; and
- non-electrified households using paraffin and candles for lighting, consume between 13 and 16 candles per month.[19]

	Quantity			Delivered MJ			Monthly cost		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Candles	34	37	36	117.3	127.7	124.2	17.00	18.50	18.00
Candles & electricity	11	12	11.5	38	41.4	39.7	5.50	6.00	5.75
Candles & paraffin	13	16	15	44.9	55.2	51.8	6.50	8.00	7.50

Table 5.20: Monthly household candle consumption

18 The category of formal households is excluded from these calculations as a relatively high percentage of formal dwellings are electrified.

19 The top and bottom figures are excluded from the observation to remove the bias of extremes.

Table 5.20 above shows the quantity, delivered energy in megajoules and the monthly cost of candles for households using candles only or combined with other fuels for the purpose of lighting. It is found that households using only candles for lighting consume 60% to 70% more candles per month than households using a combination of candles and electricity or paraffin.

5.4.1.6 Car battery consumption

Car batteries are predominantly used instead of electrical energy in non-electrified households for the provision of entertainment services. Some electrified households are still found to use car batteries. This may be attributed to these households not yet converting their appliances to electrical use. There is a need to evaluate the perceptions of households toward energy consumption of appliances such as televisions and radios.

Most households use car batteries to power televisions and/or radios. Attempts to apportion household energy consumption between the different entertainment appliances is fraught with difficulties. It is difficult to determine how much a household using a television only or a radio only consumes. Household consumption of car batteries varies according to how much households use the appliances powered by the car battery. Mehlwana and Qase (1996) found that some households restrict their use of entertainment appliances due to the perceived cost of running such appliances. For example, in one household it was found that the male head of the house restricted television viewing to watching news programmes only. The female head of the household watched other programmes only when the male head was out and the children were forced to watch television at the neighbours house (Mehlwana & Qase 1996). The price of battery charging is relatively comparative in all areas and, therefore, price alone is unlikely to affect regional variations in consumption. Therefore variations in consumption occur between individual households rather than between regions.

Area	*Electrification*		*Dwelling type*			
	Electrified	*Not elec.*	*Formal*	*Planned informal*	*Unplanned informal*	*Backyard shacks*
Cape Town	7	3.1-3.3	*	*	2.7	5
PE	*	3.8	2.5	2.6	1.6	2.5
Durban	*	2.6-3.6	3.5-4.7	3.4-4.5	3.4-4.5	*
Gauteng	0.7	2.4	3.6	4.1	4	*

Table 5.21: Car battery consumption (number of charges) per month by access to electricity and dwelling type

Table 5.21 shows that consumption ranges between 1.6 and 4.7 charges per month, with an average consumption of 3.2 charges per month. By evaluating the frequencies in the categories of low, middle and high levels of consumption, a low value of 2.6 charges per month, a medium value of 3.5 charges per month and a high value of 4.5 charges per month are put forward. Consumption of car batteries is summarised in table 5.22 below.

	Quantity			*Delivered MJ*			*Cost*		
	Min	*Max*	*Ave*	*Min*	*Max*	*Ave*	*Min*	*Max*	*Ave*
TV &/or radio	1.6	4.7	3.2	2.1	6.1	4.2	7.44-10.02	21.86-29.42	14.88-20.03

Table 5.22: Monthly household consumption of car batteries

5.4.2 Multiple fuel use scenarios

As highlighted in section 5.2.2, low-income households commonly use more than one fuel to meet their household needs. While there are countless permutations of fuel combinations used in low-income households, this section presents some of the most common combinations.

5.4.2.1 Electrified households

As shown in section 5.2.2, many low-income electrified households continue to use gas, paraffin or coal for cooking, space heating and water heating purposes, while using electricity to meet their lighting and entertainment needs. Tables 5.23 to 5.25 show the breakdown of consumption by units and delivered megajoules in households combining the use of electricity with gas, paraffin or coal.

	Electricity		*Gas*	
	Units	*MJ*	*Units*	*MJ*
Cooking: Ring/stove			24	1 176
Water heating: Ring/pot			6	294
Lighting	48.21	173.56		
Media				
TV	12.16	43.78		
Radio	2.2	7.92		
TOTAL	**62.6**	**225.3**	**30**	**1470**

Table 5.23: Breakdown of energy consumption in household using electricity and gas

Table 5.23 shows that households using a combination of electricity and gas, consume approximately 1695.3MJ per month. The breakdown of energy use in terms of delivered megajoules for households using electricity and gas is as follows:

- 69% of household energy consumption is dedicated to cooking;
- water heating consumes 17% of monthly household energy consumption;
- lighting accounts for 10% of monthly household energy consumption; and
- entertainment equals 3% of household energy consumption.

As it stands, space heating has not been included in the scenario presented in table 5.23. This is because few gas-using households were found to own gas appliances specifically dedicated to space heating.

	Electricity		*Paraffin*	
	Units	*MJ*	*Units*	*MJ*
Cooking			21	777
Space heating: Primus			16.3	603
Water heating			9.3	344
Lighting	48.21	173.56		
Media				
TV	12.16	43.78		
Radio	2.2	7.92		
TOTAL	**62.6**	**225.3**	**46.6**	**1 724**

Table 5.24: Monthly household energy consumption for households using electricity and paraffin

Households using electricity and paraffin consume, on average, approximately 1949MJ per month. Table 5.24 shows the breakdown for households consuming electricity and paraffin in terms of delivered megajoules to be as follows:

- cooking accounts for 40% of monthly household energy consumption;
- 31% of monthly household energy consumption can be attributed to space heating;
- water heating consumes 18% of monthly household energy;
- lighting accounts for 9% of monthly household energy consumption; and
- entertainment accounts for 3% of monthly household energy consumption.

In Gauteng and Durban, some paraffin-using electrified households use a combination of electricity and candles for the end-use of lighting. In these households, the breakdown of lighting energy consumption approximates the following: a total monthly consumption of

101.5MJ for lighting, with 39.7MJ (11.5 candles) being attributed to the use of candles and 61.8MJ (17.15kWh) being attributed to electricity use.

In Cape Town and Port Elizabeth, paraffin-using electrified households are often found to use a combination of electricity and paraffin for the end-use of lighting. In these households, lighting energy consumption can be broken down as follows: a total monthly consumption of 246.8MJ for lighting, with 185MJ (5 litres) attributed to the use of paraffin and 61.8MJ (17.15kWh) attributed to electricity use.

	Electricity		*Coal*	
	Units	*MJ*	*Units*	*MJ*
Cooking: Coal stove			165	4 455
Space heating: Coal stove			207	5 589
Water heating: Coal stove			41	1 107
Lighting	48.21	173.56		
Media				
TV	12.16	43.78		
Radio	2.2	7.92		
TOTAL	**62.6**	**225.3**	**413**	**11 151**

Table 5.25: Breakdown of monthly household energy consumption for households using electricity and coal

For households using a combination of electricity and coal, approximately 11,376MJ are consumed per month. Table 5.25 shows a breakdown of monthly household energy consumption in terms of delivered megajoules as follows:

- 39% for cooking;
- 49% for space heating;
- 10% for water heating;
- 2% for lighting; and
- 0.5% for entertainment services.

In some coal-using electrified households, candles are used to supplement electric lighting. This is a result of households not being fully wired and leads to the following breakdown of households lighting energy consumption: a total monthly lighting energy consumption of 101.5MJ, with 39.7MJ (11.5 candles) being attributed to candle consumption and 61.8MJ (17.15kWh) being attributed to electricity consumption.

Taking into account the exclusion of space heating from the gas and electricity scenario, the two scenarios of gas and electricity and paraffin and electricity exhibit roughly similar monthly household delivered energy requirements. In Gauteng, electricity and coal using households have substantially larger monthly delivered energy requirements. Some of this difference in delivered energy may be attributed to regional climatic variations. In the colder Gauteng region, higher space heating requirements are experienced. When comparing cooking and water heating requirements, however, it is evident that not all of the variation in delivered energy can be attributed to climate. The energy requirement for cooking and water heating for coal-using households in Gauteng was found to be 5562MJ as compared with 1121MJ or 1470MJ for paraffin- and gas-using households respectively. This represents a monthly delivered energy requirement in coal-using households four to five times greater than that in paraffin- or gas-using households. The differences in efficiency of coal appliances compared with gas or paraffin appliances is a factor of between 1.5 and 2 (see table 5.3). This lower conversion efficiency of coal appliances results in coal-using households having to use more fuel to perform the same tasks and can account for further variations in monthly delivered energy requirements.

In the above and previous sections, four main scenarios for low-income electrified households have been identified. These are households using:

- electricity only;

- electricity and gas;
- electricity and paraffin; and
- electricity and coal.

Candles are commonly found to be used in connection with the above scenarios.

Figures 5.38 to 5.41, adapted from SALDRU (1993) data, give an indication of the proportion of households in each of the metropolitan focus areas which fit into the above-mentioned scenarios.

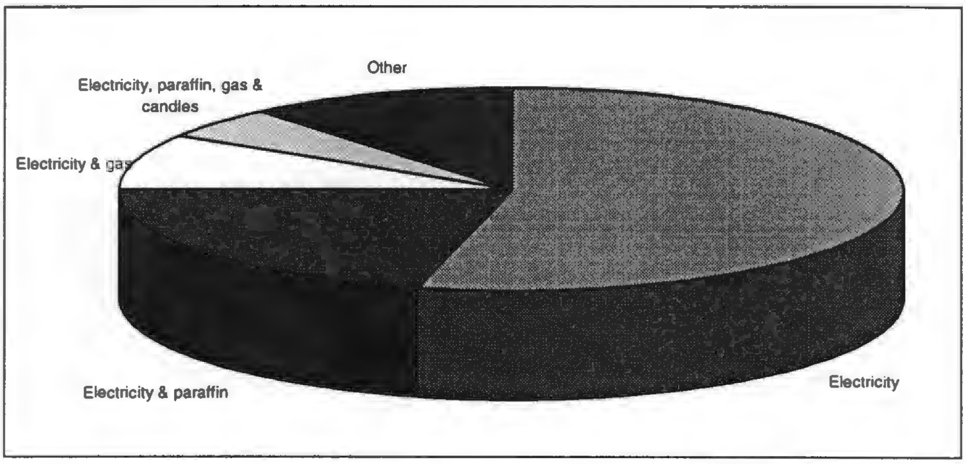

Figure 5.38: Proportion of electrified households in Port Elizabeth using different fuel combinations

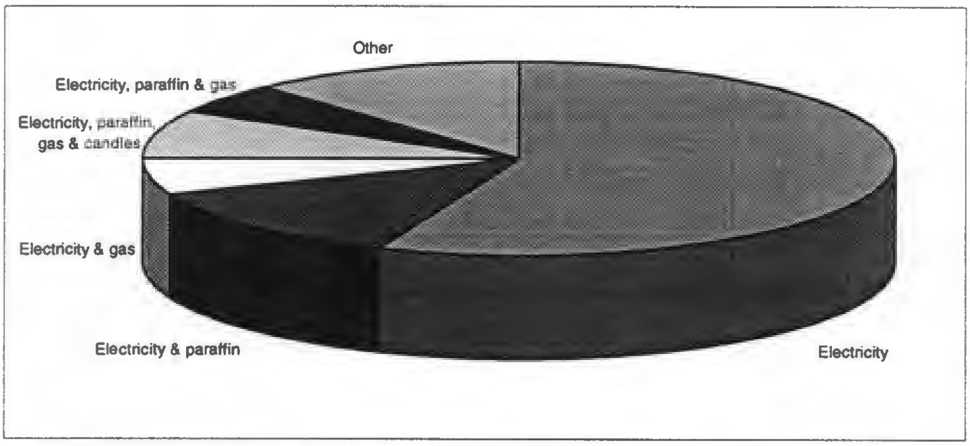

Figure 5.39: Proportion of electrified households in Cape Town using different fuel combinations

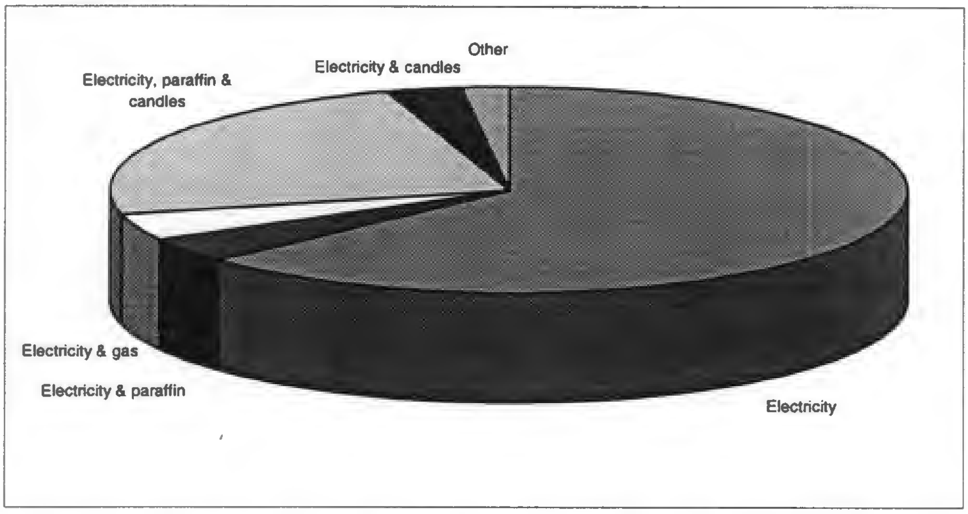

Figure 5.40: Proportion of electrified households in Durban using different fuel combinations

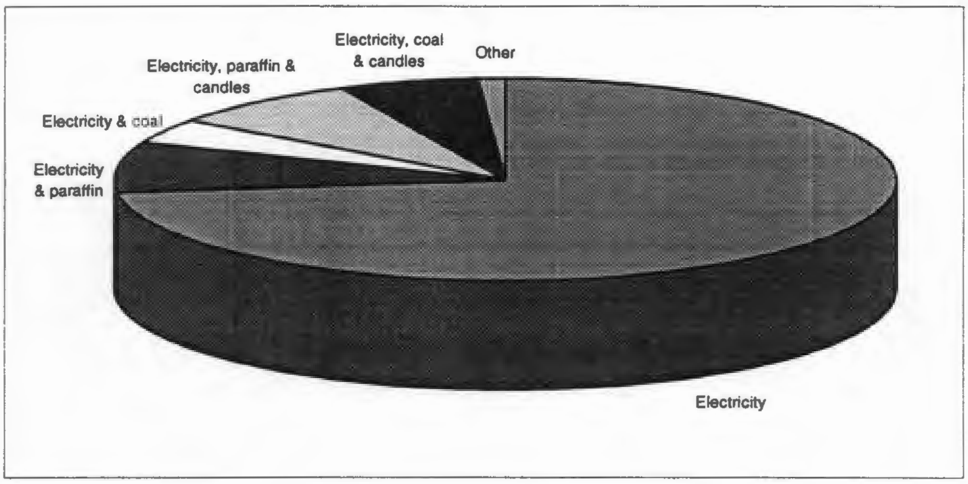

Figure 5.41: Proportion of electrified households in Gauteng using different fuel combinations

As mentioned previously, the SALDRU (1993) study is biased toward formal, long-established and slightly higher income households. It is anticipated that the number of households using electricity only is over-estimated and that a higher incidence of multiple fuel use can be expected in lower income electrified households.

5.4.3 Non-electrified households

In Gauteng and Durban, many low-income non-electrified households were found to use a combination of paraffin and candles, where candles were the main fuel used for lighting. In addition, car batteries are often used to provide entertainment services in non-electrified households.

	Paraffin		*Candles*		*Car batteries*	
	Units	*MJ*	*Units*	*MJ*	*Units*	*MJ*
Cooking: Primus	21	777				
Space heating: Primus	16.3	603				
Water heating: Primus/pot	9.3	344				
Lighting						
Paraffin lamp	5	185				
Candles			15	51.8		
Entertainment						
Television &/or radio					3.2	4.2
TOTAL	**51.6**	**1909**	**15**	**51.8**	**3.2**	**4.2**

Table 5.26: Monthly household energy consumption for households using paraffin, candles and car batteries

For households using a combination of paraffin, candles and car batteries, an average of 1965MJ is consumed per month. Table 5.26 shows the breakdown of monthly household energy consumption in terms of delivered megajoules for households using paraffin, candles and car batteries to be as follows.

- 40% for cooking;
- 31% for space heating;
- 18% for water heating;
- 12% for lighting; and
- 0.2% for entertainment services.

In Gauteng, many low-income non-electrified households were found to use coal, candles and car batteries to meet their household energy needs.

	Coal		Candles		Car batteries	
	Units	MJ	Units	MJ	Units	MJ
Cooking: Coal stove	165	4 455				
Space heating: Coal stove	207	5 589				
Water heating: Coal stove/pot	41	1 107				
Lighting: Candles			36	124.2		
					3.2	4.2
TOTAL	**413**	**11 151**	**36**	**124.2**	**3.2**	**4.2**

Table 5.27: Breakdown of household energy consumption for households using coal, candles and car batteries

Table 5.27 shows that households using a combination of coal, candles and car batteries consume approximately 11,279MJ per month The percentage breakdown of monthly household energy consumption in delivered megajoules is as follows:

- 40% for cooking;
- 50% for space heating;
- 10% for water heating; and
- 1% for lighting.

In Cape Town, low-income households were found to use a combination of paraffin, gas and car batteries to meet their household energy needs. This is presented in table 5.28 below.

	Paraffin		Gas		Car batteries	
	Units	MJ	Units	MJ	Units	MJ
Cooking			24	1 176		
Space heating	16.3	603				
Water heating			6	294		
Lighting	8.4	311				
Entertainment: TV &/or radio					3.2	4.2
TOTAL	**18**	**914**	**20**	**1 470**	**3.2**	**4.2**

Table 5.28: Breakdown of household energy consumption for households using paraffin, gas and car batteries

For households using gas, paraffin and car batteries, approximately 2388MJ are consumed per month. The following percentage breakdown of monthly household energy consumption in terms of megajoules is observed in table 5.28:

- 62% for cooking;
- 25% for space heating;
- 12% for water heating; and
- 13% for lighting.

The scenarios presented in tables 5.26 and 5.28 showing monthly energy consumption for households using paraffin, car batteries and candles or gas, indicate these two scenarios have similar delivered energy requirements. Households using coal are shown to have much higher monthly delivered energy requirements. As mentioned under the section on electrified households, these differences can be attributed to variations in climate and the energy efficiency of appliances.

In the above and earlier sections, four main fuel scenarios for non-electrified households have been identified. These are households using:

- paraffin only;
- paraffin and candles;
- coal and candles; and
- paraffin and gas.

Car batteries are commonly used in conjunction with the above fuel combinations to provide entertainment services.

Figures 5.42 to 5.45 below give an indication of the proportion of non-electrified households in the four metropolitan focus areas which fit into the above-mentioned scenarios.

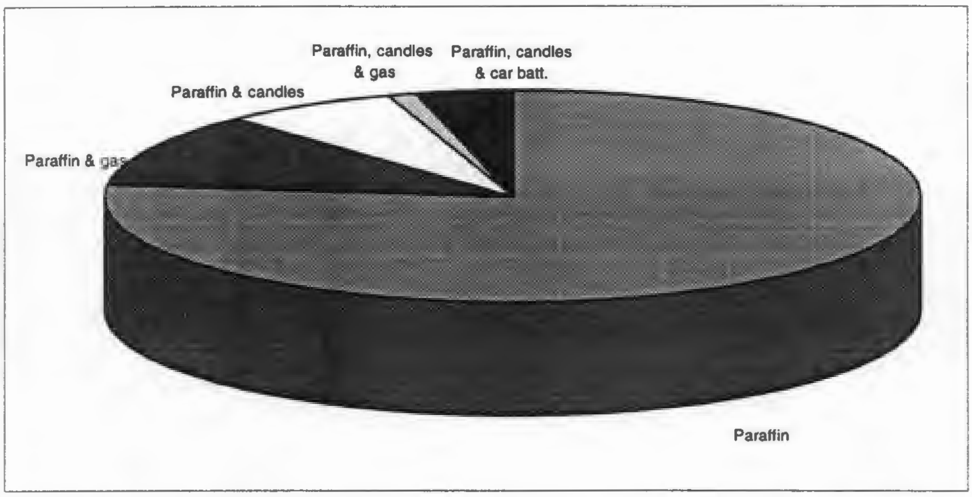

Figure 5.42: Proportion of non-electrified households in Port Elizabeth using different fuel combinations

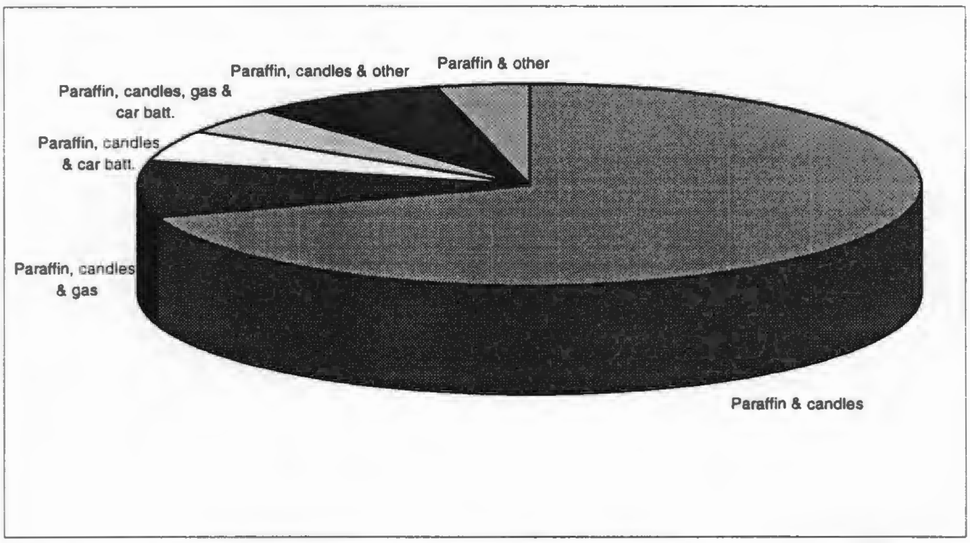

Figure 5.43: Proportion of non-electrified households in Durban using different fuel combinations

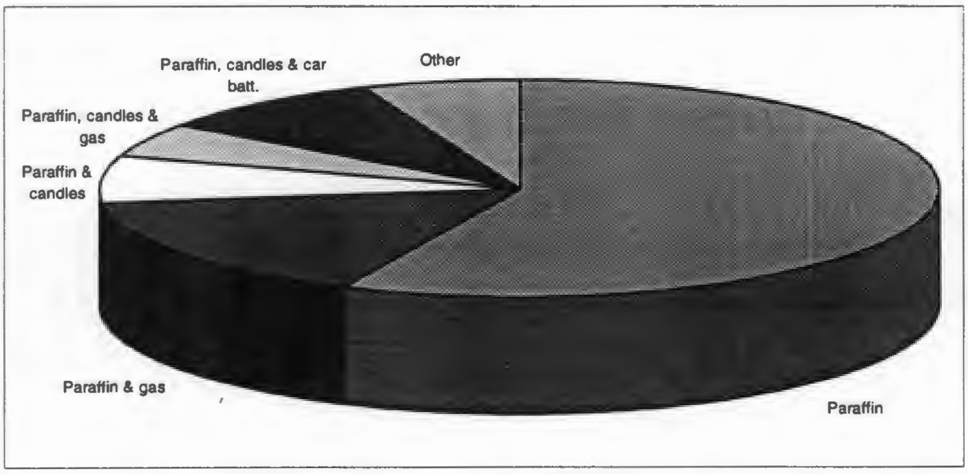

Figure 5.44: Proportion of non-electrified households in Cape Town using different fuel combinations

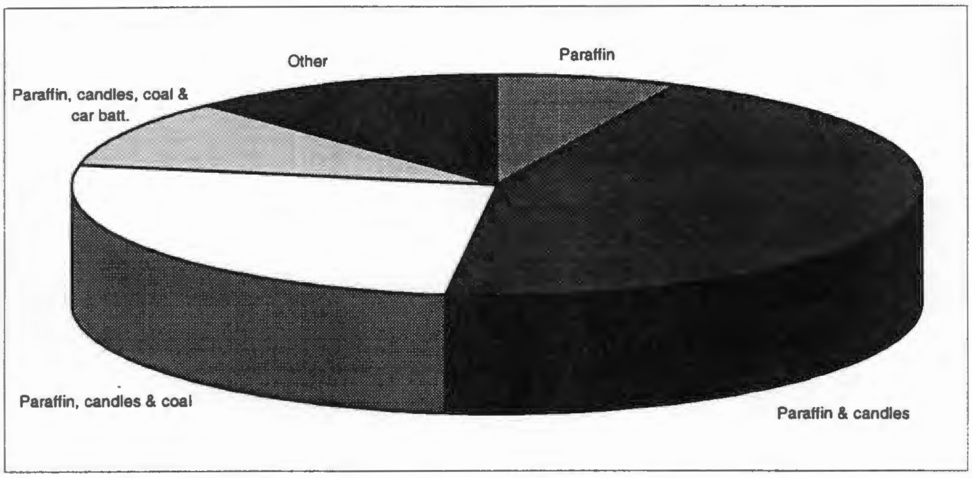

Figure 5.45: Proportion of non-electrified households in Gauteng using different fuel combinations

Figure 5.45 showing fuel combinations in Gauteng underestimates the use of coal. This can be attributed to the study being conducted in summer, when households substitute paraffin for coal. The proportion of non-electrified households using coal in winter is reported to be in the region of 63%.

5.5 Conclusion

This report has identified strong links between fuel use and the variables of geographic location, climate and socio-economic indicators such as income. In the case of electricity, additional variables such as time-since-electrification and appliance ownership have been linked to levels of household fuel consumption. There are, however, limits to the analysis presented in this report. These limitations are discussed below.

While it has been possible to give broad estimates of the amount of fuel used and energy consumed for the typical household fuel scenarios, comparing these energy sources proves to be more difficult. Levels of fuel use are strongly linked to income and other socio-economic variables and thus vary substantially between households. It is impossible to determine from the available data whether households using different fuels are receiving the same level of service and, therefore, the usefulness of comparing megajoules and cost of different fuels for different end-uses is questionable. Leach and Gowen (1987) emphasise the difficulties in using the type of data presented in the surveys used to compare end-use consumption. They state that data which is given in terms of the proportions of households which use a particular fuel to meet different end-uses, as opposed to end-use consumption in terms of energy shares, cannot be used to accurately estimate actual consumption for each fuel or end-use. They observe that this is especially true where many households use multiple fuels for specific end-uses. They further point out that 'end-use consumption is often difficult to define because one end-use [appliance] frequently provides several end-use services' (Leach & Gowen 1987: 59).

It is important to note that low-income households in South Africa often use a number of fuels to meet a specific end-use or a single appliance to meet a number of end-uses. The breakdowns of energy consumption presented above do not, necessarily, reflect the intricacies of multiple fuel use.

Some important gaps emerge out of this research. It is found that current surveys do not sufficiently analyse end-use energy consumption in terms of links between household consumption and income and time-since-electrification, two variables which appear to have significant impacts on the combinations and quantities of fuels used in low-income households in South Africa. There is a further need to establish the relationships between socio-demographic variables, such as gender, and energy use. While links between poverty and gender and the consequent implications for energy consumption can be inferred from socio-demographic data presented in the consumption surveys, there is insufficient information on the implications of gender power relations for household fuel consumption.

Furthermore, there is insufficient information on how fuels are used within households, the combinations of appliances used to meet a specific end-use and the proportion of fuel used to meet a range of end-uses. While it is recognised that there are difficulties in obtaining such information owing to the fact that households themselves are often unaware as to how much fuel is used to meet different end-uses, there is a clear need for research in this area. Specifically, there is a need to gather information on the proportion of primary fuels used relative to the proportion of secondary fuels used to meet specific end-uses. Such information could be used to validate the research presented in this paper.

Despite the shortcomings of the survey data, several important observations can be made with regard to the most significant issues for low-income households.

In chapter three, the poor thermal performance of both formal and informal low-income housing was highlighted. Owing to this low level of thermal performance, a disproportionate heating burden is placed on the poor. This is particularly evident in colder climatic areas where substantial heating is required. From the household fuel scenarios, it can be deduced that between 20% and 35% and between 20% and 25% of monthly household energy consumption (in delivered MJ) in paraffin-using and electricity-using households respectively is dedicated to space heating. In the colder region of Gauteng, it was found that approximately 50% of monthly household energy consumption (in delivered MJ) in coal-using households is dedicated to space heating. Estimates of energy savings related to thermal performance improvements such as the installation of ceilings and insulation, range between 60% and 90% of the monthly space-heating bill. Thus, it is evident that substantial energy and cost savings can be made from targeting thermal performance improvements in both new and existing low-income households.

In chapter five, emphasis is placed on the wide range of fuels used in low-income households to meet specific needs. The main fuels used in low-income households have been identified as paraffin, coal, gas, candles and electricity. Choice of fuels used in low-income households is influenced by, amongst others, the cost and availability of fuels and appliances, geographic location, income, financing or credit systems, social determinants such as fuel- and appliance-sharing networks and household size and structure, and the perceived dangers of fuel use. The efficiency of these fuels to perform different tasks varies substantially and the fuels used in low-income households to meet specific end-uses are often not the most efficient. Furthermore, there are significant health and safety implications associated with the use of coal, paraffin and candles, the most commonly used fuels in non-electrified low-income households. The welfare of low-income households can be improved by managing household fuel use in a way that the most efficient fuels for each specific household energy need are used. Development and energy policy should target and promote household energy management strategies based on efficiency and safety. Such policies will need to take into account the social and economic survival strategies identified as major determinants of current household fuel choices.

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