

Energy Supply

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ENERGY SUPPLY REPORT

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Glossary : Energy supply and public lighting

ADMD	After diversity maximum demand refers to a measure of the average peak demand in an area. This measure informs the design of a reticulation system.
Colour rendition	How various colours will appear under a specific light source
Colour appearance	The apparent colour being produced by the source of light.
Conductors	Materials through which energy (in this case electricity) can flow.
Energy service	The use of the energy when in use. Cooking, water heating, lighting and so on are examples of energy services.
Heavy thermal energy services	Services that use a lot of heat, like cooking, space and waterheating.
HV reticulation	High voltage reticulation normally considered 22 or 11 kV. Electricity is transmitted at high voltages and low currents to reduce losses during transmission.
Illuminance/ lux	Lighting levels are usually measured in "lux" - the lighting level provided by a lamp. The lux is defined as 1 lumen/sqm. Minimum recognition distance can be derived from the lux level (eg. 3 lux = 10m recognition distance; 1 lux = 4m recognition distance).
kV:	Kilovolts or 1000s of volts.
kVA:	Kilovoltamperes and is a measure of electrical power a conductor can take.
Lamp	Electrical light source that emits light due to a current being passed through its terminals. Typical types include incandescent, fluorescent, mercury vapour, high pressure sodium, low pressure sodium, halogen and tungsten. Energy consumption is rated in watts (W).
Live	An electricity conductor which has a voltage on it.
Luminaire/ Luminary	An apparatus that distributes the light emitted by a lamp. Lamps are not part of the luminaire, but all the items for fixing them, protecting them and for connecting to the supply circuit are.

Luminous efficacy	A measure of the level of light provided by the light source - this is affected by the lamp type, the luminaire, the mounting height of the lamp.
Lumen	Measure of light output intensity from a lamp.
LV reticulation	Low Voltage reticulation is typically the 400 to 220 volt supply which enters the dwelling.
Lux	See illuminance
Mounting height	Vertical distance from the centre of the light source to the surface of the road or ground.
Opposite arrangement	Luminaires are placed on both sides of the road.
Single side arrangement	Luminaires are placed on one side of the road only.
Spacing	The distance between adjacent luminaires on the same side of a road.
Short circuit:	Happens when two conductors which should not come into contact make contact.
Spazas	Small, normally home based shops which sell basic groceries.
Transformer	A piece of machinery which takes electricity at a high voltage and low current and transforms it into a low voltage high current, or vica versa, for a desired application.
Trip	An automatic switching off of electricity, if too much electricity is drawn at any one time. It is a protection mechanism in the case of a short circuit.
Utility	The supplier or distributor of a service, but can also refer to the use of the service.
XLPE	The material that provides insulation on a covered conductor.

1. Objectives of energy services

Energy supply systems are not an end in themselves. The call for electricity is a good example of this - it is not electricity per se that people are after, it is the services which electrical energy can provide. In planning for domestic energy services from an *end-use* perspective (what the consumer sees) it is useful to consider a picture of the energy service requirements within a household. Common household energy services include; cooking, lighting, space heating and cooling, water heating, refrigeration, ironing, and entertainment in the form of TV and radio. Planning for energy service delivery must take into account that energy services are likely to be accomplished using a variety of fuels even after access to electricity has been gained. However, some fuels like electricity, are the only fuels that can provide services like television and radio.

The combination of fuels and appliances have different benefits and disbenefits to end-users. These include economic efficiency, emissions at the point of use, multiple utilities of fuels and appliances, entry-cost and operational affordability, convenience and so on. These will be discussed in some detail in the text which follows, but an example may be necessary to explain and elaborate on some these aspects of services delivery.

Consider having to make a choice between cooking with gas or coal. Coal, while much cheaper than gas per unit of *delivered* energy (fuel which is bought for household use), has a low efficiency in burning and results in excessive levels of pollution at the *point of use* (where the cooking is done)¹. Gas, conversely, is an efficient burning fuel for cooking which is clean at the point of use. Coal can be burned in a stove or brazier which also can heat the house, so coal is considered to have *multiple utilities* (many uses) such as cooking, space and water heating. Sometimes the multiple utilities are not desired for instance the heat generated in the dwelling when using coal for cooking can contribute to uncomfortably warm conditions and therefore, during warmer periods of the year can be considered a disbenefit and may result in another fuel being chosen for cooking. Conversely the efficiency of cooking with gas on a stove is such that little of the energy ends up in providing other energy services. Therefore a space heater would have to be used when it is cold to fulfil household space heating requirements.

Both gas and coal stoves are expensive in *first cost or entry cost terms*. However, coal can be burned in a paint tin with holes punched in the sides (a brazier), which costs nothing. Gas has to be bought in bottles for which a deposit must be paid (unless one lives in parts of Cape Town, Port Elizabeth or on the PWV where there is existing gas reticulation). Coal can be bought in small amounts such as a hub-cap full. Cooking on a coal brazier, while expensive in *life-cycle terms* (over the life of the brazier, because of high losses of heat and therefore low efficiency), nevertheless has a low *entry cost*, and therefore is affordable in first-cost terms to

¹ This is not necessarily true for the total emissions, as coal which is burned in powerstations is transformed into electricity at an efficiency in the region of 35%.

the poorest. Generally this high level of accessibility, though lower in first cost terms, is achieved at a cost which is higher in life-cycle terms.

Gas provides instant heat for cooking and reduces the level of hazardous emissions². Compared to coal being burned in a brazier or in a stove, which takes a while to get hot, gas provides instant heat, which contributes to it being considered to be a *convenient* fuel. However, gas has seen limited applications as many people believe it to be unsafe, the reticulated distribution networks inaccessible or the bottles and appliances expensive when compared to paraffin.

The example provides an indication of the complexities of what can be considered an adequate and affordable energy service. Specific objectives of energy service provision should:

- be affordable in relation to size and frequency of incomes for the end-user;
- minimise negative impacts on the national economy;
- minimise the negative health and environmental effects of fuel gathering and energy related emissions;
- maximise convenience in use and fuel acquisition;
- be of a consistent quality; and
- maximise safety.

The distribution (transport or transmission) networks for these fuels and, to a lesser extent the method by which the appliances have been acquired, will be the major topic of this report. Clearly, the electricity network is of primary importance to planners, as this requires a reticulation network unlike other fuels, with the exception of piped gas, (this option is at present limited in scope). The remaining fuels are transported to low-income areas by road or on foot by fuel traders or end-users. The transportation infrastructure is covered in the working paper on roads.

In the household fuels contribute to energy services, which differ with respect to cost and convenience. But beyond the household energy requirements there are other socio-economic benefits which access to say, electricity, can provide. Access to fuels can enable small scale enterprises and other income generating activities. Activities such as these could include the running of refrigerators in spazas and shabeens and the powering of electric sewing machines for sewing groups. In rural areas electricity can assist with the pumping of water for irrigation. Electricity may also result in the provision of area or public lighting which when adequately provided is associated with decreases in criminal activities.

² Gas, like paraffin, is often used under unventilated conditions which can contribute to the high levels of household humidity, which can be detrimental to health and the fabric of the dwelling.

2. Service options

This paper will not attempt to arrange these supply options in relation to the levels of service as each of the different fuels can provide different services with differing convenience, economic and environmental costs to the end-user. For example all energy services can be provided by electricity, but this is not necessarily the cheapest option for all the services. Passive solar water heating and space heating can provide cheaper (in life-cycle terms) and cleaner energy services than those provided by electric water and space heating. Gas and the solid fuels can provide a cheaper cooking service, while electricity is clearly superior for refrigeration and lighting.

Table 1: Summary table of energy services and the fuels which can fulfil them (Y signifies Yes). Of course many more services could be achieved using a wet battery or photovoltaic (PV) system, but provision of heavier thermal services are unlikely from these sources because of the large capital outlays which would be incurred.

fuel	cooking	lighting	space heating	water heating	refrigeration	TV/radio
grid electricity	Y	Y	Y	Y	Y	Y
gas	Y	Y	Y	Y	Y	
PV lighting		Y			Y	Y
wet batteries		Y				Y
paraffin	Y	Y	Y	Y	Y	
coal	Y		Y	Y		
candles		Y				
wood	Y	Y	Y	Y		
dung	Y	Y	Y	Y		
passive solar			Y	Y		

2.1 Metered In-House Electricity Supply

Until recently the conventional method of supplying electricity was with metered in-house electricity supply or via credit metering. This method requires electricity end-users to pay for the service and for the amount of electricity which is consumed. This method required a substantial meter reading and billing infrastructure.

Most electricity suppliers read metered electricity consumption once a month. This is not always possible as the occupants of the dwelling may be absent, they could own large dogs, or the area could be inaccessible. In these cases an estimate is taken (with reference to previous months consumption) or the household is either requested to complete a post card or phone in their electricity consumptions. This system is being altered in some areas to allow electricity meters to be read at the boundary of the property. Meter reading or estimates provide the information for monthly bills to be sent to the electricity customers.

In South Africa in 1994 there are over 400 electricity suppliers³, and more than 1000 domestic tariffs. These tariff structures have resulted in confusion and distrust of electricity suppliers by many people who believe they are being penalised with higher tariffs than customers in an adjacent areas. In many areas blackouts occur often and meter reading and billing is irregular, which compounds the perception of a poor quality of service.

The boycott of rates, rents and service costs has brought services and electricity specifically into the political arena. The vicious cycle of non-payment of services has resulted in a reduction in the quality of services and increasing frustration on the part of both service suppliers and end-users. In 1994 the Cape Town City Council with arrears at R 50 million responded by disconnecting customers at a rate of 12 000 per month (mostly in Langa and Gugulethu).

In the light of increasing electricity arrears, electricity suppliers are finding the widespread utilisation of credit meters risky, and in answer to this have devised pre-payment metering. This is a solution which is rapidly being perceived as reducing the electricity distributors exposure to risk. As a result pre-payment metering is being marketed as the only way to go in newly electrified areas.

2.2 Electronic Pre-Payment Electricity Dispensers (EDs)

Electronic pre-payment metering has been the electricity supplier's answer to non-payment, and as such has been opposed by civic structures in areas where service boycotts have been organised. However, this technique of electricity metering is favoured by suppliers as:

- customers pay for their electricity consumption before they use electricity and therefore it is impossible for end-users to go into arrears;
- theft of electricity can be detected by examining payment records;

³ These include black and white local authorities, regional service councils, provincial councils, homeland electricity supply authorities, Eskom, and management committees.

- electricity payments (either per unit of electricity or per month) can be incrementally increased by the supplier to recoup arrears (from prior use of a credit meter) and the cost of connection⁴.

EDs are often favoured by end-users as:

- EDs allow for closer budgeting of electricity consumption within the household;
- EDs allow for more affordability of electricity amongst households with irregular incomes (as little as R 5 of electricity can be purchased at a time)⁵;
- The purchase of electricity is easy, if the location of the electricity pre-payment vendor is nearby.

EDs are a new technology and they have had teething problems which are being overcome as more manufacturers come onto the market and more is known of the faults which repeat themselves. EDs are often associated with weak electricity supply as they are sometimes provided in conjunction with circuit breakers designed to limit the household peak electricity demand. The ready board on which the ED is mounted normally includes a light fitting and one to three plug sockets and is designed so as to facilitate the extension of the in-house reticulation at some time in the future. In the interim the power supply is distributed within the house via extension cords. Normally EDs provide only single phase electricity supply, which can limit applications, for example it would not be possible to run an in-line instantaneous electric water heater, which requires a three phase supply.

As EDs are primarily being supplied to the poor newly electrified customers at present, EDs have suffered from the perception that they are second rate electricity supplies. However, the affordability benefits of this metering system appear to outweigh the negative perceptions surrounding its application, and as a result pre-payment metering is receiving a more positive reception by the newly electrified.

On the negative side, EDs are at present going through a rapid development stage which has resulted in losses some of which can be attributed to lighting and other disturbances on the electricity cables (see 4.7 below for further details).

⁴ Eskom and the Durban distributor's practice of providing the newly electrified appliances such as two plate hot-plates, irons and kettles as "starter packs" at nominal prices to speed up electricity uptake could be considered as a precedent to use the tariff as a financing facility for the purchase of further appliances.

⁵ Recent data suggests that in Khayelitsha nearly 50% of electricity purchases were of a value R 5 or less, and nearly 70% of these purchases were made more frequently than one per week.

2.3 Gas Supply

There are many kinds of gas. The most commonly used are Liquid Petroleum Gas (LPG) and Coal or Town Gas. LPG, unlike many other gases is portable in a liquid (high pressure) bottled form and is supplied by the oil (including synthetic fuel) companies. Coal or town gas is often piped gas which is transported to the point of use at lower pressure in underground pipes. The networks which provide piped gas are limited in their extent and tend to be older areas of Cape Town Port Elizabeth and some in the PWV areas.

Connection costs vary according to how far from the dwelling the gas pipe needs to be extended. Gas suppliers make the cost of connection affordable by recovering the costs of connection through the gas tariff over a period of time (see section 4.8 below for further details of gas reticulation).

Gas bottles come in a variety of sizes from 3 to 200 kilogrammes. Once a deposit is payed on a bottle it can be exchanged for a full bottle at a cost related to the quantity of gas the bottle can hold. Gas bottle supply networks begin with the oil companies and then go through several middlemen before reaching the final destination. Each link in the gas distribution chain adds a profit margin. The oil companies are doing what they can to shorten the supply chain as at present the retail price of LPG is 130% higher than the wholesale price (Palmer Development Group 1993)

2.4 Photovoltaic (PV) Lighting Systems

PV lighting is electrical lighting, where the electricity is generated by converting solar radiation (insolation) into electricity which is stored in a battery during the day. When lighting is required electrical current is drawn from the battery and converted to a current and voltage adequate to power the light bulb.

PV lighting systems have seen limited application in South Africa. These applications, have been limited to areas without access to grid electricity, as this method of lighting is expensive in first cost terms. To date less than 100 000 of these systems have been installed in SA. Applications include un-electrified urban areas and remote rural areas.

Eskom provides access to photovoltaic electricity through a Remote Area Power Supply (RAPS) tariff which includes the electricity generation systems such as photovoltaic and wind systems. Options are provided for the maintenance of the systems, and insurance for the replacement of faulty components, and refurbishment at the end of the system's life. The systems are paid for on a monthly basis at a price related to the capital costs of the system discounted at Eskom's real discount rate of 6% over a 5 or 10 year period (Ligoff 1994).

Recently a call for tenders for photovoltaic lighting systems that could provide some lighting and providing for radio and TV at costs less than R 1 500 was placed.

Several manufacturers and suppliers bid for the tender, and ten of the systems have been independently tested to verify the design specifications. Clearly this type of lighting system could see further applications in areas where there is no grid electricity if financing could be provided to assist households purchase these systems.

PV lighting could be competitive lighting system, if compared to electricity grid extension for lighting alone and there if local technicians had maintenance skills. However, the electricity for lighting may be inadequate, and may need to be extended to TV, refrigeration, cooking, ironing, water heating and so on. Such an expansion would be prohibitively expensive. But as a forerunner to grid electrification PV lighting may well be competitive per unit of light.

2.5 Wet Batteries

Wet batteries, such as car and truck batteries, are used in areas which have no access to other sources of electricity. Wet batteries are also integral components of photovoltaic systems. These batteries are used to fulfil energy services like lighting, television and radio and are sometimes used in conjunction with petrol or diesel generators in what is called a 'genset-plus' configuration.

Households that use car batteries pay prices in the range of R 3 to R 6 per charge and often end up carrying the batteries a long way in order to get them charged. This is one of the most expensive forms of energy provision per unit of energy, unless households have access to charging facilities, and adequately points out that some households will pay almost anything to gain access to the energy services that are exclusively fuelled by electricity.

2.6 Combustible Fuels

There are a number of other combustible fuels used to provide domestic energy services; these include paraffin, coal, candles, and wood.

2.6.1 Paraffin (IP)

Paraffin is not a preferred fuel, but it is widely used in South Africa for heating, cooking and lighting. Paraffin is the commercial fuel of the poor. It is an important fuel in rural areas where wood is scarce, and in urban areas near the coast. Paraffin is a fuel which can be sold in small quantities which make it affordable to households with irregular incomes. Although households will often pay high prices per unit of volume, paraffin maintains its popularity because unlike most other commercial fuels, it is locally available from spazas at anytime of day or night (van Gass 1993). Paraffin distribution is considered as one of the mainstays of spaza networks. However, the frequency of the sale of paraffin in food containers has resulted in a high rate of fatal ingestions of paraffin amongst children (van Horen 1993). Childproof containers are being considered as a way of reducing these risks.

Unlike the price of LPG, the price of Illuminating Paraffin (IP), is government regulated, but this legislation is not adequately policed. The IP price mark up averages 60% between the wholesale and retail outlets.

2.6.2 Coal

Coal provides about 80% of the country's energy. It is used as feedstock for the synthetic fuel industry (for the production of petroleum products), as fuel for electricity generation and other industrial thermal applications. Coal is also used as a fuel in the homes near the coal fields (Northern Natal, Orange Free State and the Transvaal (there is also a small field in the Eastern Cape (Molteno-Indwe)) (Mc Gregor 1993). South African coal is mostly bituminous coal which contains less sulphur, and more ash than northern hemisphere coal.

Coal for domestic use consumes only 1.6 % of South Africa's production. There is control over the pit-head price of coal but none over the final price of coal as seen by the end-user which can be as much a 300% of the bulk/wholesale price of coal (Mc Greggor 1993). Coal nevertheless is a very affordable fuel, which can be used to fulfil the thermal energy services required in the household, mostly space heating and cooking. Water jackets which can provide hot water are accessories to coalstoves. Coal, like paraffin, can be bought from merchants in quantities as small as a hub-cap.

Coal stoves constitute substantial investments for the poor, and it is apparent that the poor will not easily part with them, even in the eventuality of electrification. However, coal stoves are one of the primary contributors to urban air pollution in the households and urban areas where they are used. The total suspended solids (TSS) count has been seen to be several times the World Health Organisation's recommended limits (Terreblanche 1993). This is thought to contribute to the high levels of diseases in the upper respiratory tract, particularly amongst children. In an attempt to rectify this problem, low-smoke coals, which reduce the levels of TSS, are currently being developed by Enertek and United Carbon Products.

2.6.3 Candles

Candles are the widely used as either the only source of night light and/or as a standby when there are electricity blackouts. Candles are both fuels and appliances for lighting which have low entry costs. However, the low luminescence of the light limits the range of activities which can be achieved under such a light intensity.

Candles have been blamed for many of the fires which have gutted informal settlements in recent years.

2.6.4 Wood

Fuelwood provides the energy services for most South African households. It is the fuel that is burned on farms and in rural areas, but is also the 'safety net' fuel for poorest of the poor in urban areas. Wood is a cheap and renewable source of energy, if it is cropped sustainably. Where it is not cropped sustainably, those who gather it have to walk increasing distances to gather this fuel. In rural areas it is

women and children who are responsible for this work, which is onerous and can significantly reduce the time for other important household and other activities. If there is an energy crisis in South Africa it is in the supply and use of fuelwood, and the problems associated with the removal of ground cover. The burning of wood also results in high levels of particulates and other volatile hydro-carbons which can be harmful to health, especially that of the young.

Fuelwood stoves with chimneys can reduce the emissions of noxious gases and particulates within the dwelling, however this may result in a reduction of the efficiency of the stove. This is because heat, that may be required for space heating, is vented through the chimney with the smoke. Wood can provide heat for cooking, ironing, space and water heating energy services.

2.7 Passive Solar

South Africa has a climate well suited to the utilisation of solar energy. On average 4.5 to 6 kWh equivalent of insolation is incident per square metre in South Africa. This energy is free, however sometimes costly apparatus is required to capture the energy. Passive solar heating is an elegant and cost effective way of providing the two heavier thermal services of space and water heating. These two services are thought to be responsible for excessive loading of the electricity network in residential areas. National peak electricity demand has for the past two years coincided with the coldest day of the year and as a result, electricity suppliers are considering some demand-side management (DSM) programmes in which passive solar water and space heating (and insulation) of homes are being considered (Ligoff 1993).

In the three major climatic zones, hot-humid, hot-dry and temperate climatic regions, dwellings can be built in two that require no active space heating. This can be achieved at a cost equivalent to conventional core house (NE 51/9), that is in the region of R 200 per square metre (Ramsay 1993).

Solar water heating can be achieved with a variety of solar water heating appliances. These are described according to the arrangement of the solar collector and hot water storage vessel. These can be integral-, close-coupled and heaters which are separated from the storage tank. Some of these include the possibility of electrically boosted heating. If water is heated purely by solar radiation, this may require a change in behaviour such as bathing/showering in the evenings and missing out on washing with hot water for the few days of the year when solar radiation is inadequate to heat the water. Of course other means of heating water could be employed on these days, should hot water be essential.

* **provide an annotated graphic illustration of each service option**
(see Appendix: Graphics, Energy Supply and Public Lighting)

* indicate where examples (if any) of these service options can be found in Cape Town

Table 2 provides a list of where the different energy options can be found in Cape Town.

Table 2: Where different energy service options can be found in Cape Town.

Fuels	Where in Cape Town
metered in-house electricity supply	almost all areas supplied by the Cape Town City Council
pre-payment electricity dispensers	most of Khayelitsha
piped gas supply	Sea Point, Gardens
bottled gas	Unelectrified and newly electrified areas of Khayelitsha
photo-voltaic lighting	Unelectrified areas of the Cape Peninsula, including Cape Point Nature Reserve, Red Hill, unelectrified Khayelitsha,
wet batteries	Unelectrified areas of Khayelitsha
paraffin	Widely used in newly electrified areas, as well as in Langa and Gugulethu
coal	hardly used (4 % of households in Cape Town)
candles	unelectrified areas and areas where electricity supply is irregular, such as Khayelitsha
passive solar	CLEEPH demonstration houses in Mitchells plain, many middle class areas have roof insulation and/or solar water heaters

3. Reticulation Options

The electricity reticulation options are mainly a consideration of whether the cables should go underground, or above ground. The design options thereafter include the level of After Diversity Maximum Demand (ADMD), the capacity and level of insulation of the cables and the contracting method. Further options which should also be considered are the potential to apply DSM and the degree to which other fuels can be employed to provide some of the heavier energy services (such as cooking, water and space heating). Finally, the degree to which the reticulation can be integrated with public lighting and telecommunication services, must be considered.

The density of erven will effect the streetlighting costs per erf, but the cost per erf of electrical reticulation varies less appreciably within the range of urban densities. Sections 4 and 5, below, discuss these service options further.

3.1 Above-Ground Cabling

Above ground cabling is the most popular way of providing an electricity reticulation. It allows for the rapid stringing of cables from pole to pole. These poles can be of variety of materials including creosoted natural wood poles, carbon steel, or precast concrete. They are placed at regular intervals, and must be of sufficient height and strength to provide support for the streetlights and the telecommunications infrastructure. The cabling can be bare conductor, covered conductor or aerial bundle conductor (ABC). These are distinguished by their differing levels conductor insulation. The level of insulation has implications for how the cables are attached to the poles, with bundle conductors typically requiring no further insulation. It is this fact which makes these conductors cost competitive with bare conductors.

3.2 Below-Ground Cabling

Cabling for below ground applications is typically designed with armour plating. This cabling should also be impervious to water. It is placed underground at a depth of one metre, and is suitable for labour-based or labour intensive contracting.

Below ground cabling is neater than above ground reticulation and will result in less aerial clutter. But if street lighting is desired it will result in poles being erected to carry streetlights - poles which could have partially facilitated above-ground reticulation.

3.3 Mid-block Reticulation

Mid-block reticulation enjoyed some popularity for a time as a more efficient and cheaper option. However, there seems to be a growing consensus that the cost saving aspects of shorter cable lengths to make household connections and not having to cross streets are outweighed by the negative aspects. These include the lack of access onto private property to service the system. On very small sites, such as those of less than 200 square metres, this system can be a nuisance. As with underground cabling extra poles are required for streetlighting (at extra cost) must be placed alongside the street (it is possible to mount lamps on the mid-block poles, so reducing costs, but the streetlighting will be less effective and the system may be undesirable to the residents).

3.4 Road Reserve Reticulation

For underground reticulation a half a metre of road reserve is required. Above ground road reserve reticulation would occupy a pole's width of space. Sub-stations and transformers would occupy some further space for both options, however,

transformers can be mounted on poles above ground (see appendix: graphics). This method would therefore avoid any further claim on road reserve.

* **provide an annotated graphic illustration of each reticulation option**
(see appendix: graphics)

4. Costs

The issues affecting the cost of energy services are related to the type of infrastructure/apparatus required to fulfil the energy services, the cost of money, the parameters included and excluded in the cost build-up and desired profit margins.

The cost build-up includes the capital cost of the *fixed* infrastructure required to provide the service and the *operational* costs of providing the service. There are other costs which are considered as externalities, these can include the environmental, security of supply costs, the opportunity cost of the labour of wood gatherers and so on. These last costs, which do comprise real costs to the national economy, can be reflected or internalised in the price/tariff build-up of the fuel or planning for the use of these fuels. Without a costing framework to incorporate externalities planners could be object led in incorporating these costs, in other words planning could be oriented towards minimising these negative externalities.

The fixed infrastructural costs in the case of the petroleum products (paraffin, LPG, and candles), coal and wood are the costs required to buy the machinery and site it so as to refine, mine and/or cut and dry the fuel and the infrastructure to transport it to the point of sale. In the case of electricity infrastructural costs would include, the powerstation, the transmission lines, switch gear and transformers the service connection and the meter. In the case of solar energy there are no costs of production, transportation or metering. However, if electricity is required from the solar energy, the cost of transforming the solar energy to electrical energy (in the photovoltaic panel) and storing it could be considered as the infrastructural cost.

The operational costs would include the cost of the primary fuel. Barrels of oil (or coal in the case of synfuel products) for the petroleum products and other process inputs, and coal or gas and other operational inputs in the case of electricity. For commercial fuelwood production, operational costs could include the growing of seedlings in nurseries, seedling planting and management of woodlands, the cutting, storage, distribution and marketing of fuelwood.

4.1 The finance costs

The finance costs of money varies depending on the credit worthiness of the purchaser. An institution such as BP or Eskom with high credit worthiness would be charged low real discount rates in the region of three per cent per annum, whereas a poor would be required to pay a high interest rate, if they could borrow it at all, because they are considered as high risk borrowers. The Usury Act

prescribes the highest rate by law, this is a nominal rate and can be as high as 30 per cent per annum (depending on the rate of inflation).

To the poor end-user household which does not enjoy access to credit facilities or only access to money at very high interest rates, the cost of this money provides an effective barrier to accessing efficient and low life-cycle cost energy service. The household would be limited then to low first (or entry) cost fuel and appliance combinations, which can be excessively expensive in life-cycle terms. This is particularly the case with more efficient fuel and appliance combinations which could reduce the costs to the end-user while reducing environmental impacts. Both points are pertinent to contributing to the alleviation of poverty.

4.2 Energy service supply infrastructure

This infrastructure includes all the apparatus that is required to provide the fuel, to transport/transmit the fuel, the equipment to meter or measure the fuel, the personnel required to manage the supply of energy and the appliances within which the fuel is burnt or used to provide the desired energy service/s.

4.3 Cost parameters

4.3.1 Cost of electricity

Both petroleum products and electricity in South Africa have price build-ups which reflect the fixed and variable (operational) costs, however in the case of electricity these costs are not always reflected in the price. This is apparent in the different tariffs offered to end-use sectors by different distributors.

Examples of price build-up which does reflect cost is the S1 tariff, as published in 1992.

Table 3: Price build-up of the Eskom S1 tariff in 1992

Costs (cents/kilowatthour)	Contribution to cost	Total cost (excluding VAT)
Bulk supply costs	10.35	10.35
Losses at 7%	0.73	11.09
Support costs	2.80	13.89
Network replacement	0.27	14.16
Network Capital recovery	4.68	18.84

This is the case for the Eskom S1 tariff, however, other electricity distributors have other ways of pricing. For example the Cape Town City Council buys electricity in

bulk⁶ and then prices the electricity in order to achieve a surplus from sales of electricity. This surplus from sales is used to cross-subsidise the property rates base which is used to cover other services, many of which are not traded. This tacitly results in a subsidy to property rates.

4.3.2 Cost of Paraffin and LPG

Similar price build-ups can be constructed for IP and LPG these are presented below.

Table 4: Price build-up of LPG and IP April 1993

Cost (cents/litre)	LPG	% of total	IP	% of total
In bond landed cost	40.418	34.3	57.898	53.0
Railage equalisation	1.1	0.9	-	-
Service differential	9.7	8.2	9.7	8.9
Distribution cost differential	25.3	21.5	-	-
Government taxes and levies	3.6	3.1	7.0	6.4
Wholesale margin	18.8	15.9	13.672	12.5
Zone differential	7.5	6.4	0.2	0.2
Cylinder differential	16.8	14.3	-	-
Safety levy	0.3	0.3	-	-
Slate under/over recovery*	(5.718)	(4.9)	(6.430)	(5.9)
Wholesale price	117.8	100.0	81.93	75.0
Legislated dealer margin	-	-	27.3	25.0
Legislated price to consumer	-	-	109.24	100

(Source: Mc Greggor 1993)

⁶ Bulk electricity prices are related to the consumption of electricity and the peak demand for electricity.

4.4 The differential between actual wholesale price and required price based on price build-up

As mentioned above, there are limits to the level of profit or surplus that energy suppliers can make in the case of paraffin, however in practice this price is not monitored. All other fuels are priced according to what the market can bare, with the exception of electricity, which is controlled in the case of Eskom.

The price of electricity supplied by local government is not regulated in South Africa. In many instances Eskom, as a single purpose authority, has to apply for a licence to distribute electricity from South Africa's electricity regulator, the Electricity Control Board. Eskom's financial plan is passed yearly by the Electricity Council (the board of stakeholders which formulates Eskom policy). The council determines Eskom's financial policy, including the surplus it makes. This amount is used internally for objectives such as the balancing of the debt equity ratio, which in principle would allow for borrowing of capital for future powerstations at a favourable interest rate. Eskom is obliged to pass on costs and benefits to end-users.

The 400 plus electricity distributors all have different tariffs, some of which may coincide. Each distributor determines its level of surplus or loss on the sale of electricity, according to a variety of economic and/or political variables. There are other aspects which alter infrastructural price, for example at the time of writing Eskom was promising a subsidy of R 400 for each new electricity connection made within the country, no matter who was making the connection.

The operational costs are also altered by local authorities who are in a position to reduce the peak electricity demand by running their own powerstations, through the use of pump-storage facilities⁷, or by shedding load, such as turning controlling hot water geysers. Local authorities with electricity generating facilities can use these to reduce the peak demand for electricity and therefore reduce the price paid for bulk electricity. Because of the near 40 per cent over-capacity in electricity generating capacity, Cape Town City Council is encouraged to keep its powerstations out of commission. The encouragement is in the form of a bulk tariff rebate.

Maintenance, service and refurbishment costs are not separated in tariff build-ups (with the exception of the S1 tariff mentioned above), although there is a trend at present to make tariff structures more transparent. It is therefore difficult to separate what portion of the costs of electricity provision can be attributed to these costs.

⁷ Cape Town City Council owns a pump storage facility near Somerset West. The principle of this operation is to pump water to an elevated reservoir when electricity demand is low, and then release the water to run through turbines when the demand is high to 'lop' off the peak demand for bulk electricity purchases.

4.5 Demand-side Management and the Time-of-use tariff

Electricity suppliers are vulnerable to the instantaneous demand for electricity because they have to generate it at the same time as it is used. The Time-Of-Use (TOU) gives time related price signals to encourage customers to use electricity during off-peak periods. TOU is available to industrial customers, and is at present being piloted for use amongst domestic customers.

TOU is one of a range of strategies to intervene on the customer side of the meter to influence and change the magnitude and/or the shape of the customers' electricity load. This in turn has implications for the amount of generation required and the capacity of the infrastructure. These strategies are grouped together as Demand-Side Management (DSM) options. DSM options aimed to change the electricity demand patterns of small-customers (including domestic electricity users) are being tested by Eskom. Included are TOU tariffs, water heating options, appliance labelling, more efficient lighting options and thermal comfort improvements (Ligoff 1993). DSM is a utility initiated strategy aimed at increasing the optimisation of their resources. They are designed to reduce the utility's fixed investments and operational costs while maintaining the same level of service. However, for the customer to adopt DSM measures, encouragement will have to be offered.

To give an indication of the magnitude of savings, consider the following example. A one bar electric radiant heater typically draws 1 kW of energy when in use. To establish how much generating capacity is required to meet the 1 kW demand it is necessary to understand the losses in the electricity distribution system. In the annual report for 1992, Eskom (1993) presented figures which suggested that 8% of electricity is consumed by their powerstations are lost during transmission, and that powerstations in 1992 were available for 76.7% of the time. This would imply that a generating capacity required to power the one bar heater is $1\text{kW} \times 1.08 / 0.767 = 1.4 \text{ kW}$. The average cost for the electricity supplier for new power generating facilities is in the region of R 5 000 per installed kilowatt. It therefore stands to reason that unless that generating investment can be utilised, it may be more profitable to the electricity generator to encourage the end-user to provide their heating service by using another energy carrier such as gas, paraffin, or by reducing demand for commercial energy through better thermal performance of the dwelling. The implementation of such strategies have in many countries proved to be a cheaper options to many electricity suppliers than unabated growth in demand for electricity.

DSM measures will alter the cost of the energy service to the end-user, and can also result in the absolute conservation of commercial energy. Conservation of this sort implies reduced emissions of pollutants, and therefore environmental benefits.

4.6 Costs of energy services to end-users

The cost to the end-user of achieving cooking, space, water, lighting and refrigeration utilising various common fuel and appliance combinations, is presented in the figures below. All prices of fuels were those recorded in 1992. The costs of the appliances were the costs of new appliances paid by end-users during 1992. These figures were drawn from reports or requested from retailers. The cost of access to gas bottles, and electrical connections are included. The prices are brought forward to the beginning of 1994 using the consumer price indices (CHI)⁸ and a real discount rate of 5 per cent is used.

Figures 1 to 5 present the life-cycle cost estimates for a range of energy services. The figures give an indication of the cost range as experienced by the end-user in fulfilling the service. These are presented as maximum and minimum costs per 10 megajoules (of heat or cooking, space and water heating) of utilised (useful) energy, per 1 000 lumenhours of lighting, and as a daily energy cost for running a 200 litre refrigerator. The maximum and minimum costs per month are provided for some specific household tasks.

Throughout this exercise assumptions have been made, such as the number of hours which the appliance is in use and the average number of watts that a variable power appliance utilises. The full details of calculations, including the cost components of the life-cycle cost appear in appendix A.

The heat required to do an arbitrary cooking task of bringing which requires 5 litres of water at 20 degrees centigrade to the boil daily, is presented in figure 1.

⁸ The CHI may not be the appropriate mechanism to bring all prices forward. This is particularly relevant to the price of electricity, as Eskom has undertaken to reduce the price of electricity by 20 per cent in real terms over a 5 year period. 1994 is the third year of this commitment.

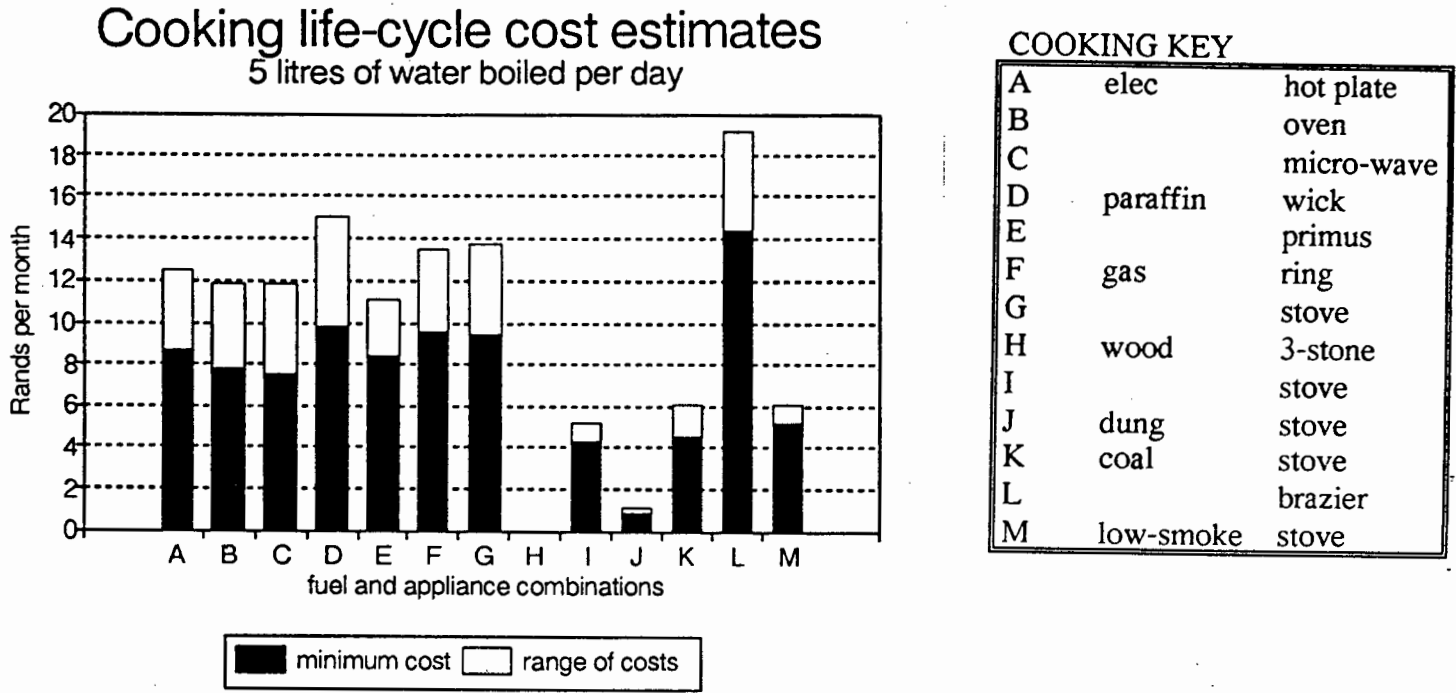


Figure 1: Life-cycle costs estimates for cooking
(Source: Thorne 1994)

It is clear from figure 1 that the solid fuels (wood, coal and dung) are the cheapest options for cooking, followed by the petroleum fuels and electricity. While the solid fuels can produce emissions hazardous to health, the petroleum fuels are relatively clean. Electricity is the cleanest fuel at the point of use, although electricity⁹ and petroleum fuels produce emissions and hazardous wastes which are associated with generation and refining processes.

The estimates do not take into account the convenience of the speed at which cooking takes place. For example, while the solid fuel stove takes a while to heat up gas cooking provides instant heat. Of all the cooking processes, microwave cooking is probably the fastest to deliver useful energy.

⁹ Emissions can be reduced through the use of renewable energy sources such as wind, solar and hydro (without dams).

The arbitrary measure of space heating required is equivalent to using a one bar electric heater for 4 hours daily. The cost of space heating options to achieve equivalent heating for other fuel and appliance combinations is presented in figure 2.

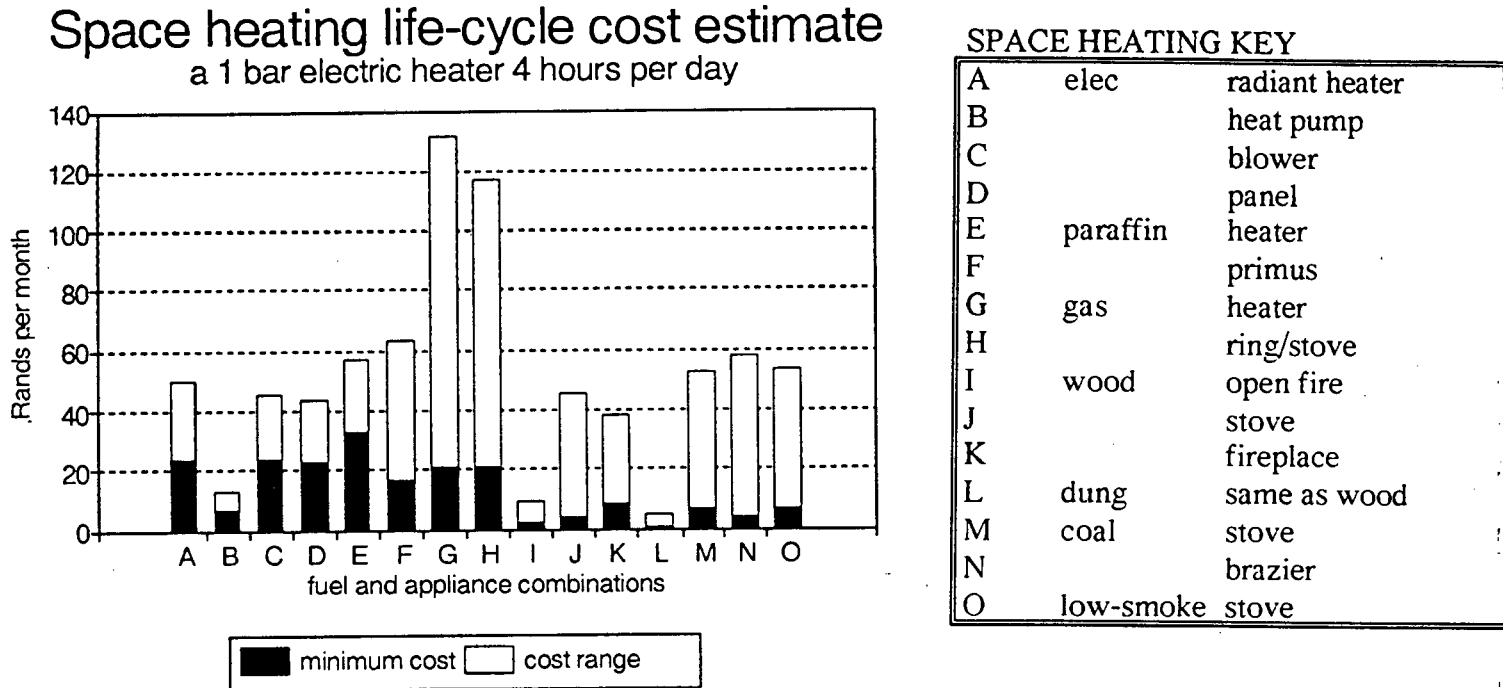
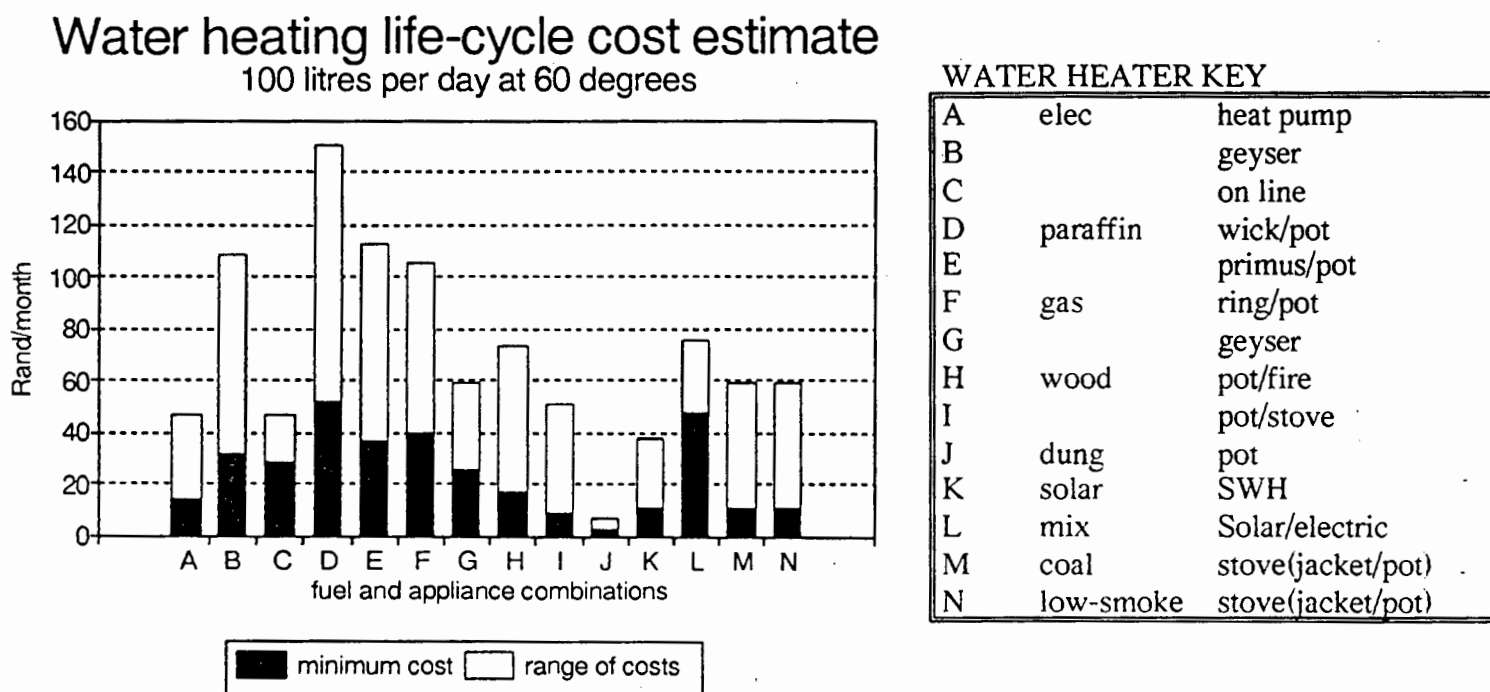


Figure 2: Life-cycle cost estimates for space heating
(Source: Thorne 1993)

Passive thermal design is not included in these calculations, however if no extra costs are incurred in building a dwelling which uses less energy than a structure which is not as thermally efficient, the replaced heating energy is delivered at zero life-cycle cost. Other than passive heating, solid fuels and the electric heat pump could provide low cost space heating.

In figure 3 the of the life-cycle cost estimates of providing hot water are presented. The arbitrary quantity of energy that is required to heat 100 litres of water per day from 20 to 60 degrees centigrade is the basis of the cost estimates.



WATER HEATER KEY

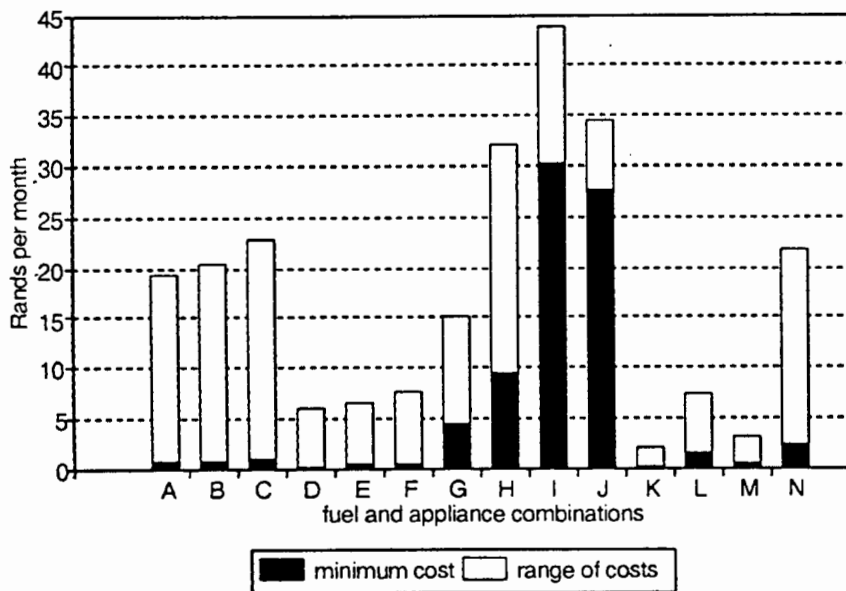
A	elec	heat pump
B		geyser
C		on line
D	paraffin	wick/pot
E		primus/pot
F	gas	ring/pot
G		geyser
H	wood	pot/fire
I		pot/stove
J	dung	pot
K	solar	SWH
L	mix	Solar/electric
M	coal	stove(jacket/pot)
N	low-smoke	stove(jacket/pot)

Figure 3: Life-cycle cost estimates for water heating
(Source: Thorne 1994)

For water heating, solid fuels and solar water heaters (SWH) provide lowest cost options, with electric heat-pump the best electric option.

The life-cycle costs of providing lighting for a 4 hours of lighting per night. This cost bears no reference to the light output of the lighting appliance. It is important to note that in order to cost like quantities, a fraction of the cost of the connection to electricity is included (10%), so that the PV lighting systems could be compared to the other options.

Lighting life-cycle cost estimates 1 and 4 hours of light per day



LIGHTING OPTIONS

A	elec	incandescent	40W
B			60W
C			100W
D		fluorescent	12W
E			20W
F			40W
G		mercury vapour	400W
H		sodium vapour	250W
I		PV (< R 1500)	
J		PV (Eskom Raps tariff)	
K	paraffin	Hurricane	
L		Pressure	
M	gas	Pressure	
N	candles	Candles	

Figure 4: Life-cycle cost estimates for lighting
(Source: Thorne 1994)

In this case the light of a paraffin lantern, and electric light and a candle can be compared, but this says very little about the quality of the light.

Figure 5 compares the cost of providing similar quantities of light. In this case the cost is in cents per 1000 lumen hours is presented.

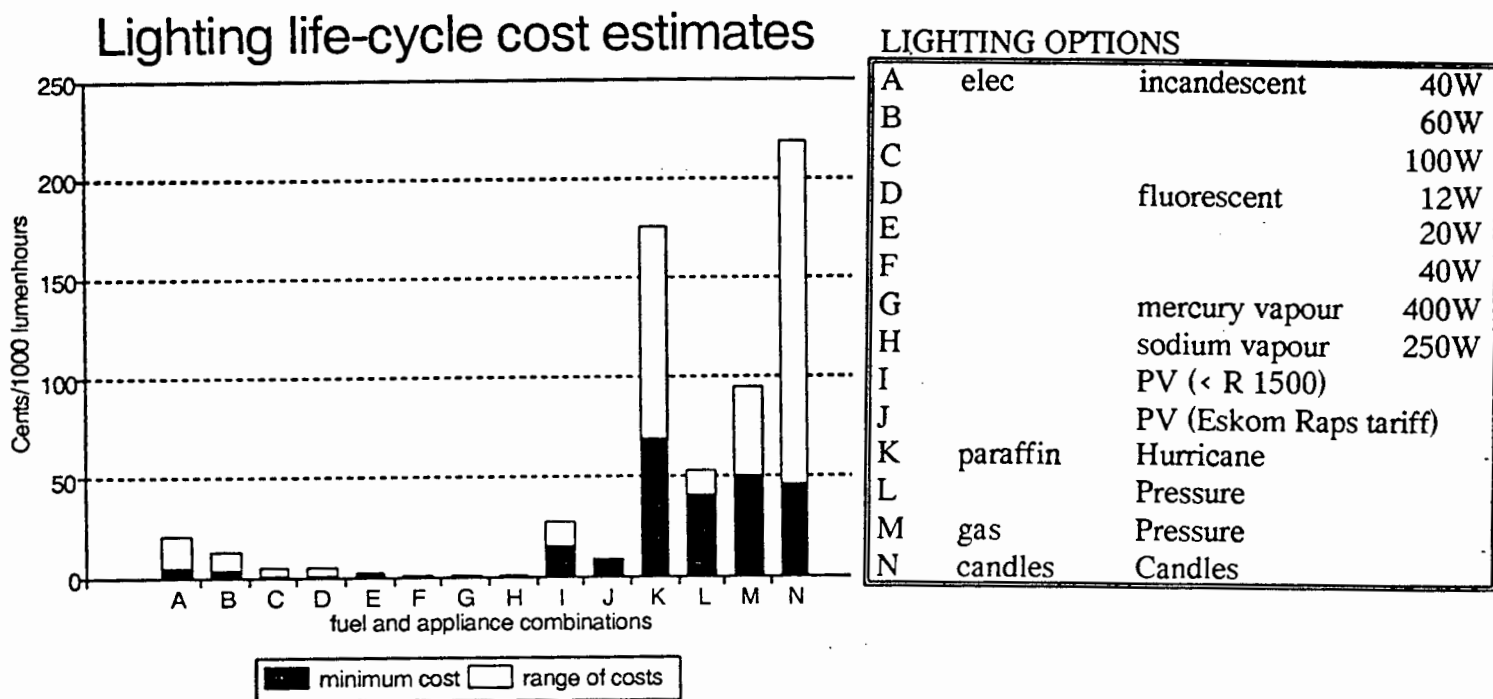


Figure 5: Life-cycle cost estimates of providing 1000 lumen hours of artificial lighting
(Source: Thorne 1994)

The electric lighting options are the most cost efficient for the delivery of light. Of these the high pressure sodium lamps are the most efficient, however the current lamps provide too much light for internal lighting, and are more suited for outdoor street or public lighting. This leaves the fluorescent lighting as the most effective indoor lighting option. While these lamps are more expensive in first-cost terms, over their life-cycle they use about a quarter of the energy of an incandescent bulb providing equal lighting. Fluorescent lamps therefore provide a cheaper lighting service than incandescent lamps.

The analysis of light output may not be the only way to consider the costing of lighting options. Costing could also be considered with respect to the light source itself - for example a candle may provide sufficient lighting for internal lighting, and can therefore be compared with a 60 watt incandescent light for a particular application.

Figure 6 compares the life-cycle costs of a range of refrigeration options.

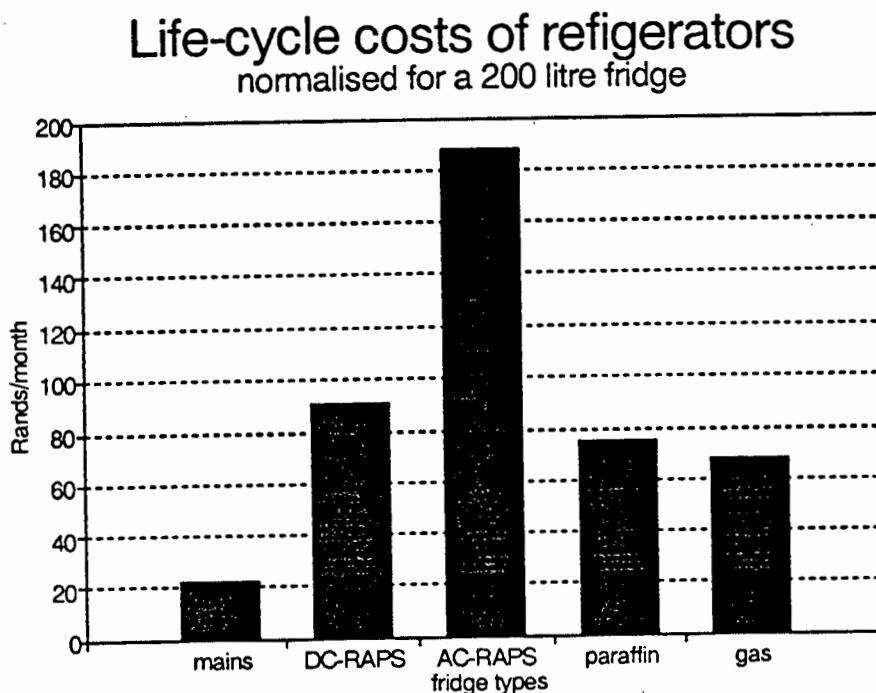


Figure 6: Life-cycle cost estimates for refrigeration
(Source: Cowan et al. 1992)

In this case the electric fridge is the best option, with gas and paraffin being cheaper than RAPS options.

The above figures give an estimate of the life-cycle costs as experienced by to the end-users of the energy service for different domestic energy services, and gives an idea of the complexity of making rational cost related decisions on which fuels and appliances to use for which service. Clearly electricity is not the best fuel in life-cycle terms for all energy services. For least-cost energy plans to be made appliances and fuel combinations must be tested and labelled according to their cost efficiency. Credit facilities could be provided through fuel suppliers to enable the access, particularly to women, to more efficient appliances.

In terms of the cost of providing the service, it is considered that the electricity reticulation would be of most interest to planners all other energy carriers (other than gas reticulation) are brought to the dwelling via the pedestrian or vehicle access routes. In the case of gas reticulation, this is normally the responsibility of a private concern, nevertheless cost estimates for different gas technologies are presented below.

4.7 Costs as experienced by the electricity supplier

Indication of the costs of providing electricity as seen from the electricity distribution and supply authority perspective are presented. In most cases the cost of the electricity reticulation is passed on to the end-user, either as an up-front connection cost, included in the price of the new house or the cost it is recouped through the tariff. In the latter case the electricity supply authority acts as a financier for the infrastructure, unless the end-user decides to pay for the entire connection cost up front. In a greenfield development, if the electrical infrastructure is installed during the initial site development, then the costs would be born by the developer who would pass this on to the purchaser of the erf. In such a situation the mortgage lender would act as the electrification financier of the High Voltage (HV) and Low Voltage (LV) reticulation. Either way the electricity users end up paying for the reticulation, and should arguably be considered as the planners' clients.

4.7.1 Reticulation

The method of reticulating electricity, either above ground or below ground reticulation, affects the cost of electrification. For the LV reticulation this is usually more expensive as the cabling above ground, however there is little difference in the above or below ground service connection costs (Northrop 1994).

It is possible that the life-cycle cost of underground cabling may be competitive, but there is no hard local data to support this, opinions vary according to the practices employed by the electricity distributors. Certainly there is an increased scope for the contribution of labour-based or labour intensive construction methods for underground reticulation.

The possibility of sharing poles with the telecommunication infrastructure has been recently implemented, where the electrical cabling is mounted higher up the poles than the telecommunication cables (Jansen 1993, Northrop 1994). At present the arrangements between electricity utilities and telecommunication companies give little incentive to the former to practice an integrated approach to reticulation. This contrasts with streetlighting, which is often a service provided by the same utility which provides electricity. If poles are alongside thoroughfares, these can and do double up as streetlight mounting.

4.7.2 After Diversity Maximum Demand

Beyond the cost of the hardware and labour involved in the infrastructure, electricity suppliers are extremely sensitive to the demand for electricity. The vulnerability is not only related to the level of electricity consumption, which effects the rate at which the capital costs of the infrastructure is recovered, but the level of the electricity demand which, in the case of domestic electricity users, fluctuates considerably over a 24 hour period. The cost of supplying this demand relates directly to the electricity supply authority's ability to buy or generate electricity at the same time as it is used.

The After Diversity Maximum Demand (ADMD) is a measure of the maximum demand for electricity amongst a group of electricity end-users and is an important criteria for designing the electricity infrastructure. ADMD effects the size of cabling and more importantly the capacity of transformers, one of the most costly items in electrification. Recent design and implementation experience varies as to the extent of the sensitivity, but all agree that this aspect of design is in fact the most crucial cost determining variable. Recent experience of Eskom suggests that the cost of providing electricity for a design ADMD of 4 kVA is double that of providing for an ADMD of 0.5 kVA. Table 5 provides some indication of how these costs vary with ADMD, erf size and percentage of those accepting electricity as variables.

Table 5: The relationship of ADMD and erf density to the cost of electrical supply

ADMD (kVA)	Rands/erf 20 erfs/hectare	Rands/erf 40 erfs/hectare	Rands/erf 100 erfs/hectare	% electricity acceptance level
0.5	1410	1350	1200	100
4	2720	2520	2400	100
0.5	1760	1690	1500	80
4	3400	3155	3000	80

(Source: van Wyk 1994)

The relationship between the cost of reticulation per erf is compared for different erf densities and different ADMDs in figures 7 and 8. Figure 7 provides the cost of material per erf and figure 8 the cost of material, labour and streetlighting (in the case of the CPA figures only). The data sources are from Eskom and CPA which are summarised in appendix B.

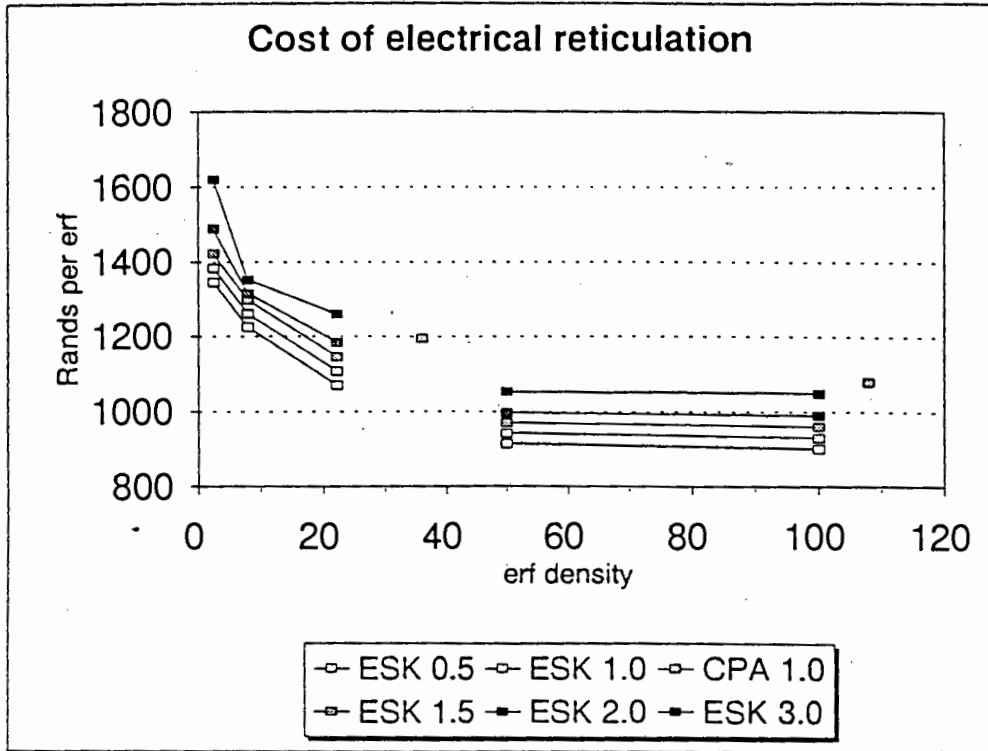


Figure 7: The cost per erf of the materials for electrical reticulation at different erf densities and ADMDs (see appendix B)

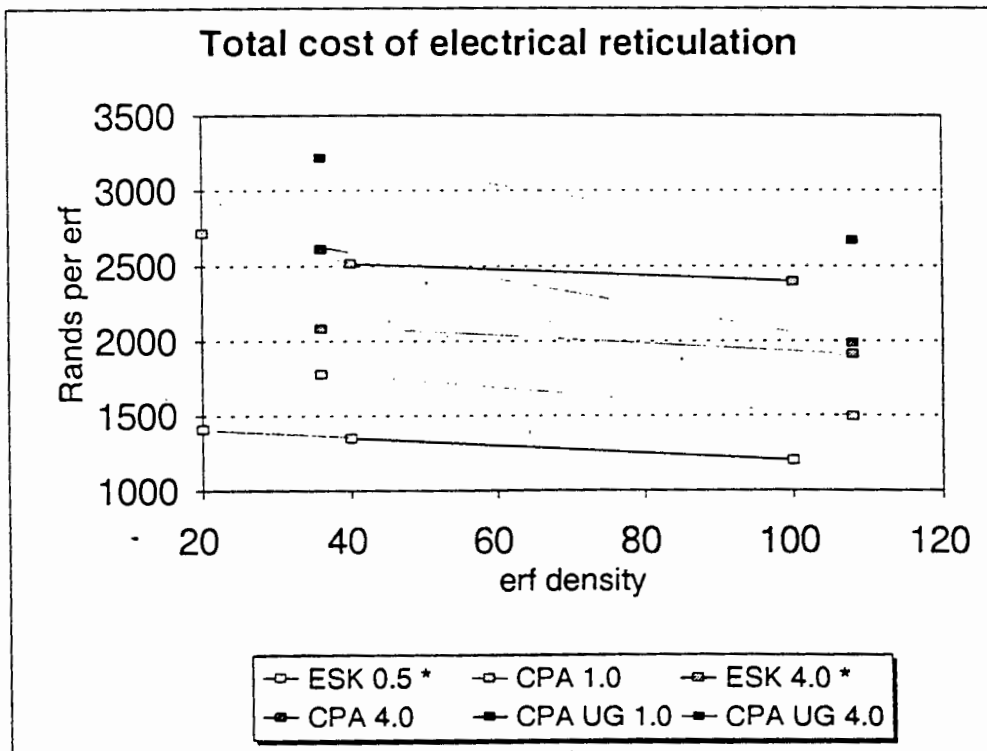


Figure 8: The total cost of electrical reticulation for different densities and ADMDs (see appendix B)

These figures confirm that the cost of the electricity supply is closely related level of supply per household (ADMD), and to a lesser extent the density of the erfs. The least-cost electrification option is above ground at high densities (greater than 50 dwelling units per hectare) and low ADMDs. It would therefore be reasonable to provide a low ADMD and then increase the size of the transformers as the demand for electricity increases, while simultaneously providing DSM options.

Other options for reducing the costs include:

- reducing the costs of the materials such as the meter, cables and poles;
- transformer size and positioning (to maximise the advantage of diversity); and deregulation of reticulation and wiring standards¹⁰.

Table 6 summarises the data in appendix B and provides per metre and per erf costs for the different reticulation technologies. The table provides data for material alone and for the entire job, including material, labour and streetlighting.

¹⁰ This last option could provide lower first-costs at the expense of safety and quality of supply.

Electrical reticulation material costs per domestic supply point											
1. Materials only											
who?	ESKOM	ESKOM	CPA	ESKOM	ESKOM	ESKOM	ESKOM	CPA	CPA	CPA	CPA
technology?	ABC	ABC	ABC	OH	OH	OH	OH	ABC	UG	UG	UG
ADMD kVA	0.50	1.00	1.00	1.50	2.00	3.00	4.00	4.00	1.00	4.00	4.00
plot size du/ha	ESK 0.5	ESK 1.0	CPA 1.0	ESK 1.5	ESK 2.0	ESK 3.0	ESK 4.0	CPA 4.0	CPA UG 1.0	CPA UG 4.0	CPA UG 4.0
92.59 108.00			1079.79					1486.10	1163.21	1891.19	
100.00 100.00	900.85	930.39		959.93	989.46	1048.54	1078.08				
200.00 50.00	914.48	942.11		969.74	997.37	1052.63	1080.26				
36.00			1195.71					1490.52	1550.95	2082.39	
450.00 22.22	1069.29	1107.18		1145.07	1182.96	1258.74	1296.63				
1250.00 8 du/ha	1223.99	1260.47		1296.95	1315.19	1351.67	1369.91				
4000.00 2.50	1345.04	1384.04		1423.04	1489.02	1620.97	1686.94				

2. Completed work: Materials, streetlights and labour (costs per domestic supply point)							
ADMD	ESKOM	CPA	ESKOM	CPA	CPA	CPA	CPA
du/ha	OH	ABC	OH	ABC	UG	UG	UG
ADMD	0.50	1.00	4.00	4.00	1.00	4.00	
du/ha	ESK 0.5*	CPA 1.0	ESK 4.0*	CPA 4.0	CPA UG 1.0	CPA UG 4.0	CPA UG 4.0
108.00		1495.00	1912.06	1984.67	2670.68		
100.00	1200.00		2400.00				
40.00	1350.00		2520.00				
36.00		1777.96	2086.71	2614.96	3219.75		
20 du/ha	1410.00		2720.00				

3. Completed work: Materials, streetlights and labour (costs per metre of road frontage (rands/metre))							
ADMD	ESKOM	CPA	ESKOM	CPA	CPA	CPA	CPA
du/ha	OH	ABC	OH	ABC	UG	UG	UG
ADMD	0.50	1.00	4.00	4.00	1.00	4.00	
du/ha	ESK 0.5*	CPA 1.0	ESK 4.0*	CPA 4.0	CPA UG 1.0	CPA UG 4.0	CPA UG 4.0
108.00 23		65.00	83.13	86.29	116.12		
100.00 28	42.86		85.71				
40.00 63	21.43		40.00				
36.00 66		26.94	31.62	39.62	48.78		
20 du/ha 100	14.10		27.20				

UG = Underground
OH = Overhead
ABC = Aerial Bundle Conductors
CPA = Cape Provincial Council
du = dwelling unit
ha = hectare

Table 6: Summary table of costs of electrical reticulation (summary of appendix B)

4.7.3 Labour based and labour intensive contracting

In a country with large numbers of unemployed people there has been interest in public works such as electricity distributors and consulting engineers in utilising practices which increase levels of employment in the area receiving electricity for the first time. Two methods of delivery which have been used recently are labour intensive and labour based contracting methods. Both have resulted in electricity connect costs lower than conventionally achieved. An example of this is the Joint Operating Company, Pambili Nombane's electrification of Khayelitsha. Pambili Nombane intends utilising labour intensive construction method there for the 60 000 new household connections over the next 3 years. The mandate is to electrify the area at the least cost. Their projected cost per connection for an ADMD of 1.5 kVA for a density of 54 dwelling units per hectare is R 1483 and has the envisaged breakdown as outlined in table 7.

Table 7: The cost of reticulating parts of Khayelitsha (please note that part of the HV system is in position prior and the cost of this is not included in this tender quote)

			Rands
Design			25
Pambili Nombane Supervision			43
Eskom Insurance			3
Contracts General Costs (incl. Site Office, Training, Insurance etc.)			155
	Material	Labour	
11 kV work (excluding poles)	134	18	152
Poles (all voltages)	79	37	116
LV work (excluding poles)	145	41	186
Services	646	157	803
Total	984	253	1483

(Source: Roucole 1994)

This technique of electrification results in approximately 15 to 20% of the cost of electrification being spent on labour. Figures for underground electrical reticulation reveal 27 to 35% of the reticulation costs being spent on labour. These figures could be extended to include materials provision during electrification, maintenance of vehicles, but as yet consulting engineers are reluctant to consider this route, unless the client¹¹ insists on this as part of the brief. In providing some sustainable employment, the local labour component can be increased through the training of front-line fault detectors, pre-payment vendors, and appliance repair technicians in the area receiving.

It has been suggested that increasing in the employment has other economic benefits which will increase the affordability of energy and other services, to the benefit of suppliers and end-users.

¹¹ The term 'client' in this case refers to the electricity distributor, however it is debateable whether the client should not be the recipients of electricity, as in the long run they will be paying for the reticulation, through the tariff. The distributor normally maintains the network, and raises finance for its extension.

4.8 Costs of gas reticulation

Gas reticulation has not emerged much contemporary debate on the provision of energy services. This is primarily because South Africa has not enjoyed access to natural gas fields, although recently natural gas has been used to produce synthetic fuels at Mossgas. This situation is changing as natural gas fields have been located and are about to be exploited in Southern Africa.

Natural gas is a valuable feedstock for the petrochemical and plastics industry, however it is also a clean burning domestic fuel. It is costly to liquify in most cases because of the presence of methane, but it can be piped to the point of use at near atmospheric pressure. Figure 9 provides a the cost for different densities using different types of piping. The data behind this figure is presented in appendix C, and is considered to be within 20% of the actual project costs.

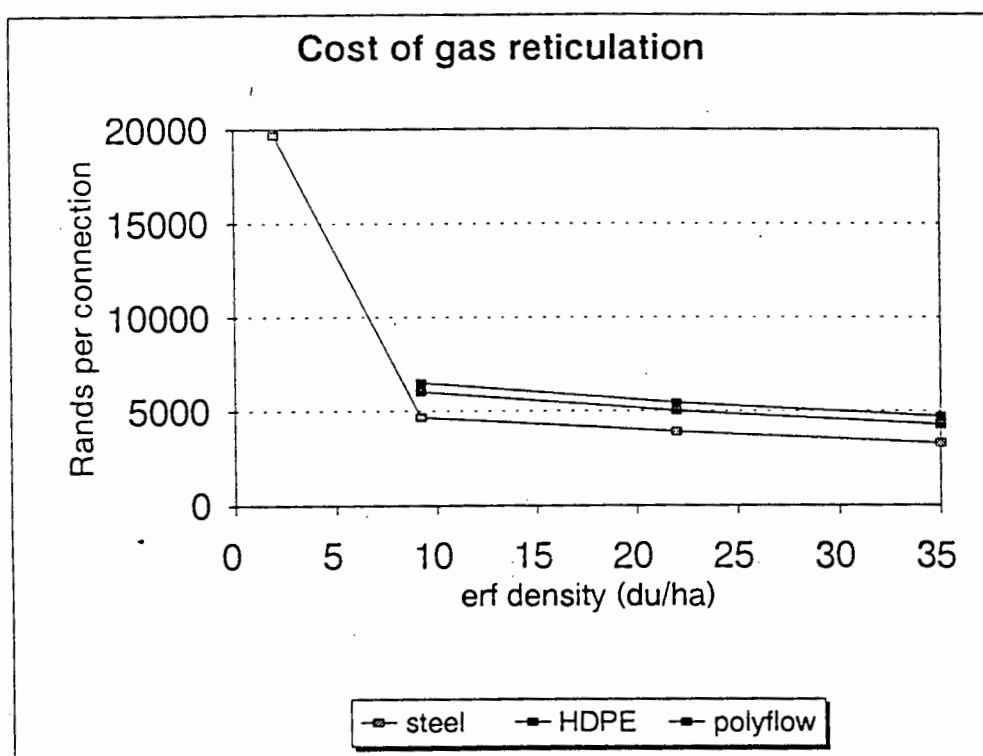


Figure 9: The costs of gas reticulation per erf using different piping technologies (see appendix C)

(source: Boyes 1994)

It is clear that this is a costly reticulation option, that is almost twice the current costs of electrical reticulation. If this capital expenditure were to be recovered at 10% per annum then the costs according to consumption would add nearly R 1 per kilogramme of gas used for those in the lowest consumption category of 1 Gigajoule approximately 20 kgs per month (Boyes 1994) (see 8.1.5)

It may be useful to use gas for more of the heavier thermal energy services, particularly if full use of passive solar energy services for space and water heating are not utilised. For cooking, gas may be competitive, however if this is the only gas using energy service, piped gas may result in providing for an underutilised reticulation network.

4.9 Costs of maintenance, service and operation

The cost of maintenance, service and operation for electricity were not available from distributors. So in order to get an idea of what the sum of these costs could be the 1994 S1 tariff build-up was used. The S1 tariff structure is based on 11.74 of the 21.75 cents/kWh (excl.vat), being required for maintenance, service and operation. The new S1 tariff also suggests that breakeven on that tariff is calculated to be 537 kWh/month, implying that $12 * R 0.1174 / kWh * 537 kWh / month = R 756.85$ is required to cover these costs per customer!

Appendix D provides an indication of the cost per metre of road frontage.

4.10 Update of the costs of the cost of fuel infrastructure

For the costs of electrical reticulation in the Western Cape the following institutions may be able to assist in giving an update of the costs electrical reticulation. Particularly useful would be Pambili Nombane¹², a joint operating company which has been mandated to provide electricity to the residents of Khayelitsha at the lowest possible cost per connection.

Staff of the Electrical Contractors Association (A.J. Clarke 021-4622690, electrical contractors such as Rob MacNamara at VKE (021-239281) and clients of the electrical contractors such as Cape Provincial Administration (Brent Hampton 021-4833154, Paul Northrop 021-4833155), Eskom (Herman van Heerden 021-9152758, Cape Town City Council (Peter Klein 021-4003353), Pambili Nombane (Alain Roucole or Mac Mdinge 021-9516711), and Western Cape Regional Services Council (Dion Veldsman 021-4872223).

To keep updated on the costs of generating electricity Cape Town City Council or Eskom are the only electricity supply authorities in the region with the capacity to generate electricity.

Coal gas reticulation is handled by the companies involved in gasification. In Cape Town these are Citi Gas and Cape Gas. For natural gas reticulation, W.M. Boyes of Central Energy Fund ph: 011-883 1000, would be a good contact person.

¹² In this endeavour the pooled expertise of Eskom, Electricite de France (France) and the East Midlands Electricity (Britain) will be applied to the electrification of Khayelitsha.

The prices of the petroleum fuels (LPG and paraffin) can be obtained from the oil companies such as Engen, Caltex, BP, and so on¹³. These companies may not be able to report or update on the price paid for fuels even those such as paraffin, as they do not have control of the price build-up to the end of the chain of delivery. However, these companies can provide the legislated price of the fuel, and give an indication of the price build-up to the point where it leaves their area of control. Thereafter the studies sponsored by Department of Mineral and Energy Affairs (DMEA) notably Richard Palmer (011-8869992) should provide a good indication of the price seen by the end-user. This method of gathering information applies to candles, paraffin, LPG, and coal.

Solar power is for nothing, and therefore there no distribution bodies. However, institutions representing the solar industry such as the Solar Energy Society of Southern Africa (SESSA), can advise which of their members are in the field, and an idea of the level of insolation across South Africa. SESSA members include academics, solar water heater manufacturers and distributors, photovoltaic manufacturers and system supplies, consulting engineers and others. A contact person would be Glynn Morris (021-7892980). For passive thermal design Dieter Holm (012-463226) or Graham Ramsay (021-6502375) may be of assistance.

Wood distribution is less formal than the other commercial fuels, and other than the DMEA's biomass initiative there are few institutes to contact. Anton Eberhard serves on the steering committee of this initiative (021-650 3230).

5. Comparison of electrical reticulation options

5.1 service and reticulation options best suited to 'greenfield' and 'upgrade' developments

As mentioned above there are many fuels and appliance combinations that can fulfil the range of household energy options. However, for infrastructural planning purposes, electricity is the only fuel network which requires consideration. This is primarily because the distribution network links closest to the end-users for other fuels (with the exception of reticulated gas networks) are informal by nature.

The electricity supply procedure normally involves finding the closest contact to HV reticulation (11 or 22 kV) which is then reticulated to the centre of the site or is led around the outside of the site (normally above ground with bare conductors) where substations which house transformers and switches are situated. The siting of substations has an important bearing on the overall cost of the scheme. These should be near the load centres, and where shopping centres, schools, and other amenity buildings are to be supplied. The sub-stations catering for these loads should be sited so that any spare transformer capacity can also serve nearby residential consumers.

¹³ Sasol has the monopoly on candle production.

To obtain effective use of the LV distributors, distribution should start as soon as possible after leaving the substation. It is desirable that a substation should be sited as close as possible to the building line or public open space, and also where distributors can radiate outwards without obstruction (NBRI 1987).

Where a HV is stepped down to LV using a transformer, feeders are taken to provide typically from 70 to 150 erfs on a circuit. LV reticulation implies a 400 volt supply between any of the alive conductors, but 230 volt between any of the alive conductors and the neutral conductor.

The cables are then hung as bare, covered or bundled conductors between poles and/or taken underground to the point of use. The reticulation for public lighting normally precedes the reticulation for household connections, unless it is predetermined by developers that the services to the site should include electricity from the onset.

The three types of conductors have various advantages and disadvantages. The bare and covered conductors need to be separated on the poles by insulators as they are either uninsulated or semi-insulated. If a bare conductor falls to the ground or gets caught in a tree, the electricity will flow into the earth causing a "short circuit". This will result in the bare conductor being "earthed" and tripping (turning off) the power supply to that conductor, rendering the cable harmless. However, if the conductor makes contact with a person while falling to the ground while still "live" it could be dangerous. Aerial bundle conductors (ABCs) and covered conductors are an attempt in part to avoid this occurrence.

The covered conductor is covered with a thin layer of a material known as XLPE. In contrast to the bare conductor, the covered conductor will not immediately trip the electricity supply when it falls to the ground, this could happen some time later (within minutes). During this period, the covered conductor is "live" and can give a shock to anyone who comes into contact with it.

The bundle conductors are insulated and therefore do not need to be separated on the pole. On falling to or touching the ground the covered conductor is considered as safe as the cable is insulated, though the conductor within the cable can stay "live", with possible though unlikely hazards. ABC appears to avoid the dangers posed by bare or covered conductors should they snap and fall to the ground.

These three types of reticulation cost approximately the same amount per connection, and can be put under ground at extra cost. The extra cost would include the armouring and moisture protection of underground cabling as well as the labour involved in burying them. Whether this offers a substantial increase in the life of the conductors is uncertain, what is certain however is that fault detection can be more complicated if the reticulation is underground and should the system require upgrading, the unearthing of the cable can result in further cost. Underground cable and associated transformers are often overdesigned to avoid the costs of possible upgrade.

Therefore for greenfield developments or in urban upgrades where the thoroughfares are straight, above ground reticulation to the edge of the erf is the most cost effective way to go. Thereafter, above ground or below ground to the dwelling is much the same in cost terms. Above ground cabling has the benefit of providing both public lighting and telecommunications infrastructure in addition to household electricity supplies, which otherwise may contribute to cluttered aerial reticulation. Should thoroughfares not be straight, then to avoid hanging conductors above dwellings, (which could incur risks), or completing short spans between poles, some electricity distributors suggest underground cabling could be a better option than above ground (Hyde 1994), though this assertion was not tested. Users of ABC say that there is no problem with using it above houses because of its extra insulation, and that the spanning of ABC above houses is common practice (Hampton 1994).

At very high densities and multi-story residential areas underground reticulation for the service connection would be the most suitable reticulation option.

5.2 Social implications of various electrical service options

The social implications of the various fuel and appliance options which provide the household energy services are primarily related to utility, convenience and affordability of the various options. For example, electricity offers a range of utilities which are broader than any of the other fuels. Electricity is the only fuel which can provide television, radio and powertools, it also provides the cheapest refrigeration and lighting options. These utilities can facilitate learning and activities such as small scale industries and business activities which would have social benefits. The quality of electrical lighting can extend the time during which these and other household activities can be conducted.

Electricity, while not the cheapest option for all energy services, is affordable in terms of the cost of access and per unit consumed, thanks to low costs of access and pre-payment metering. The tariff could also facilitate the access to more efficient appliances, and result in DSM measures which would provide benefits to the electricity suppliers, end-users and the national economy.

5.3 The environmental conditions and the implications these have for the various electrical service options (eg. wind, sunlight, water table, soil, etc.)

The strong corrosive winds, high water table, the density of the soil, the occurrence of trees affect the choices of reticulation options. For example, the sandy soil of Khayelitsha was referred to as one of the reasons for opting for labour based underground electricity reticulation there during the first phase of accelerated electrification there.

The choice of cables and the spans of these cables are also affected by the wind and corrosion factors, with bare conductors being the most exposed to weathering and shortcircuiting on trees, other cables and so on. The water table is not considered as

a major problem with respect to either above ground or below ground reticulation. Under ground cabling is sufficiently protected to reduce leakages to earth, whether it is damp or dry earth.

The frequency of poles for LV reticulation is greater than is required for adequate public lighting.

5.4 The relative advantages and disadvantages of the various energy service options.

Table 8 provides a summary of the advantages and disadvantages of different energy service options.

For simplicity the energy service options will be limited to electrical reticulation, in which the levels of ADMD ("low" 0.5 to 1.5 kVA, and "standard" or "std" 4 kVA), the type of conductor ("bundle" or "bare"), and whether reticulation is above (ag) or under ground (ug) are the variables. It is assumed that an EDs is used for metering the household electricity supply.

Photovoltaic and candles for lighting; paraffin, wood, gas, coal, and low-smoke coal cooking; as well as passive solar space and water heating are included for comparative purposes.

Table 8: Comparative advantages and disadvantages of energy services

fuel	affordability	cost efficiency	safety	convenience	environmental quality
1a. elec, ag ADMD low bundle	good for utility and end-user	good option for both utility and end-user if demand is low	good but not perfect	easily installed, elec. appliance usage may be limited	ugly in areas without trees
1b. elec, ag ADMD std bundle	good only if electricity demand has reached the ADMD otherwise not affordable for utility	good only if electricity demand has reached the ADMD otherwise wasteful	good but not perfect	easily installed	ugly in areas without trees
1c. elec, ag ADMD low bare	good for utility and end-user	good for utility and end-user	fair but falling live wires are dangerous	good, elec. appliance usage may be limited	less intrusive than bundles
1d. elec, ag ADMD std bare	good only if electricity demand has reached the ADMD otherwise not affordable for utility	good only if electricity demand has reached the ADMD otherwise wasteful	fair but falling live wires are dangerous	good	less intrusive than bundle
1e. elec, ug ADMD low	poor affordability for utility as upgrade will be costly	fair, if electricity uptake uses capacity	excellent	inconvenient for upgrading and maintenance	excellent except during maintenance and upgrades
1f. elec, ug ADMD std	possible life-cycle advantage over above ground cabling.	fair, if electricity uptake uses capacity	excellent	inconvenient for upgrading and maintenance	excellent except during maintenance and upgrades
2.PV lighting	not affordable unless access to credit is assured	better than most offgrid options for quality lighting	safe	good except on days of low insolation	excellent during use

3.candles	easily affordable (in first cost terms)	not good in light output, fair as a light source	blamed for fires	convenient	good
4.paraffin cooking	affordable (in first terms and life-cycle terms)	fair	fair	good multi-utility appliance	smoky, water vapour emissions, paraffin poisoning possibilities
5.LPG cooking	not readily affordable in first but affordable in life-cycle cost terms	fair	perceptions of safety are negative	convenient	good, but water vapour is produced
6.coal cooking	readily affordable in first cost terms (or use in brazier), but stove is a big investment.	very good near coal fields	fair with possibility of burns	excellent multi-utility appliance	poor, contributes to high levels of emissions and suspended particulates
7.low-smoke coal cooking	As this fuel is still being designed not enough is known. However,the design is aimed at reducing suspended particulate emissions.				
8.wood cooking	readily affordable in open fire, not stove	cheap but can be labour intensive	fair with possibility of burns	excellent multi-utility appliance	poor, contributes to high levels of emissions and suspended particulates
9.passive solar space heating	affordable in new formal structures, not in retrofitting	excellent	safe	convenient	good
10.passive solar water heating	affordable in new formal structures, not in retrofitting	good	safe	with electric booster heater convenient	good

6. Implications for Layout Design

For information on this section refer to section 3 of this report, appendix: graphics and section 6 on layouts of the *Public Lighting* report.

7. Supply Agencies of the service options identified

The household supply of electricity remains the domain of local government, with a few exceptions where Eskom have gained the right of supply. In all other instances fuels are supplied by the private sector, with differing lengths of supply chains (see table 4). Fuelwood is a notable exception. Although there are large private wood merchants, fuelwood is predominantly gathered by those who use it. Therefore, in the case of fuelwood, the suppliers are the same as the users. This has bearing on fuelwood policies.

Below in the table 9 are the primary suppliers of the fuels. An exception is the case of electricity where the distributors are listed.

Table 9: Supply agencies in the various cities

	PWV	Cape Town	Durban	Port Elizabeth	Bloemfontein	East London
electricity	Eskom, Local Authorities, Regional Service Councils, Provincial Administrations, Joint Operating Companies,					
coal	coal merchants					
wood	wood merchants and end-users					
paraffin	Shell, BP, Caltex, Engen, Total, Zenex and, Sasol.					
LPG	Shell, BP, Caltex, Engen, Total, Zenex and, Sasol.					
coal gas	Gascor	Citi gas, Cape gas				
solar	n/a	n/a	n/a	n/a	n/a	n/a
candles	Sasol					
low-smoke coal	low-smoke coal is still being researched by Enertek (CSIR) and United Carbon Products/University of the Witwatersrand					

8. Cost Recovery

Energy services are one of a range of services which readily recover costs if pricing is cost reflective. There are examples, mentioned above, of authorities which use the sale of electricity as a 'cash cow' for the cross-subsidisation of other non-traded services. However, access to energy is seen as more than just a fuel, it is also seen as a social good or even as a right. Amongst fuels, access to electricity is highly politicised, so much so that it is no longer considered a luxury.

The environmental problems associated with many of the fuels used in households, resource depletion of wood (where its use can contribute to desertification), oil based fuels and coal are not included in the price structure. Neither are the costs of the emission of particulates, greenhouse gases and other gases born by the supplier. These all have societal cost implications such as health costs which could well be carried in the pricing of the fuel. Internationally the trend is towards discouraging harmful emissions through disincentives such as taxes on dirty fuels, and in the case of electricity, to provide licences only to generation facilities in which the emissions are controlled. Encouragement is also provided for the conservation of commercial fuels. Such scenarios are likely in South Africa in the future, as most of our major trading partners have global warming abatement strategies, and will insist on buying goods or investing in industries that have good environmental records.

Other aspects which affect the price of the fuel, are whether or not the energy supplier should subsidise one end-use sector more than another for national or other gains. At the time of writing much debate around these issues and their relationship within the domestic sector were underway, including the principle of whether or not small users of electricity should be cross-subsidised by the large users of electricity. As a contribution to an equity principle this makes sense. However, this could be seen as a digression from cost-reflectivity.

8.1 Cost Recovery Policies

Most local government distributors of electricity set tariffs on the basis of a cost plus philosophy. This implies that both electricity bulk costs (and in some instances their own generation costs) are added to costs of provision and maintenance of infrastructure amongst the entire consumer base. The cost recovery is expanded by some distributors (such as Port Elizabeth) to include recovery of the cost of public lighting. To this amount is added the desired surplus, normally destined as a contribution to the property rates. The tariffs for the different sectors are set once the desired degree of cross-subsidy has been factored in. The cross-subsidy is most often from the industrial to the domestic sector. The lack of industrial customers in many of the areas supplied by black local authorities is one of the reasons why tariffs in these areas are often higher than in white local authorities. The National Electrification Forum has proposed the concept of a national domestic tariff, designed to avoid the inequitable arrangements of the present cost plus philosophies, but in an effort to still recover the costs of electricity provision.

It is considered that cost recovery should be one of the fundamentals of fuel pricing. However, more recently there have been considerations of other important social and environmental costing criteria. For example, within the domestic sector, should the poor small user of electricity be cross-subsidised by the wealthy large users? And to what extent should environmental degradation or adverse health implications, which both impact on the national economy, be reflected as a cost?

These are questions being vigorously debated within the National Electrification Forum working group on finance and tariffs. And they are debates which will be taken up by electricity regulatory authorities in the future.

What is clear from international experience is that while access to electricity can be driven as a political policy issue, the price should not be exposed to too much political interference. The tariffs should be designed to recover the cost of the electricity generation without jeopardising the long term viability of the electricity providers to provide electricity.

8.1.1 Bulk electricity

Bulk electricity costs are recovered in relation to consumption of, and demand for, electricity. The cost of providing for peak demand is therefore passed onto the bulk customer, providing the incentive to minimise the ratio of electrical peak demand to consumption, in other words even up-take of electricity - encouragement which has yet to be passed on to the domestic end-user.

8.1.2 Electrical connection cost recovery

The cost of high voltage (HV) and low voltage (LV) reticulation is passed on to the developer in one form or another. There appear to be two ways in which this is done. Either the developer puts in the HV and LV reticulation and passes this cost on to the purchaser of the erf; or, the developer is obliged to put down a deposit to guarantee a certain level of electricity consumption after a period of time.

In the former case the cost is recovered through the mortgage. In the latter, the guaranteed level of electricity consumption, would result in adequate surplus to cover the cost of the extended network. Should this electricity consumption target not be reached, the developer forfeits the deposit¹⁴.

8.1.3 Service connection cost recovery

Where electricity is to be delivered to an area from the onset, electricity authorities normally arrange for service connections to be made after the developer has put in most of the HV and LV reticulation. This is either covered in part or in full by a cash payment, through a specific cost item on the bill or through the tariff. The Eskom S1

¹⁴ This latter method of recovery is the method used by the Cape Town City Council. While it does create the environment for the timely installation of the electrical network, it can create an incentive for the developer to install inefficient hot water geysers, or not to install roofing insulation so as to encourage electrical uptake.

tariff above is an example of such a tariff. Normally the tariff would also include an item designed to cover the refurbishment costs of the grid.

8.1.4 Capital and operating/maintenance cost recovery

These costs are included as items within the tariff, however there have been occasions in the past when maintenance (and/or service costs) have been fixed items on the monthly bill, no matter how much electricity is consumed. The capital costs of generating plant and the major transmission costs have been spread out over all end-users of electricity. This capital outlay is recovered through a consumption related tariff, which translates into: the more electricity used the more the consumer pays¹⁵. This energy related tariff also reflects the operational costs of generating electricity.

A more cost reflective tariff variation is the time-of-use tariff which is based on the philosophy that it is more expensive in capital and operating terms to provide for peak demand for electricity. Therefore, at times of the day when the demand for electricity is low, TOU prices are low, and when demand is high, TOU prices are high. Into the tariff is built the incentives and disincentives for energy demand behaviour to change to suite the suppliers.

8.1.5 Cost recovery of reticulated gas distributors

Table 10 provides an indication of how the cost of the gas network is recovered, for different gas usage scenarios.

Table 10: The cost recovery for gas reticulation at 8% per annum at different levels of consumption

sector	units per hectare	% connected	Capex R per unit	Usage - Gj ¹⁶ /month		Charge R/Gj (8% capex pa)	
				low	high	low usage	high usage
residential	35	80	3 298	1	2	27.49	13.74
	22	80	3 909	2	3	16.29	10.86
	9	80	4 677	3	4	12.99	9.74
commercial	9	80	4 677	20	40	1.95	0.97
light industry	2	80	19 475	800	1500	0.20	0.11

¹⁵ This is not the case in Soweto where electricity users pay a fixed rate for electricity no matter how much they consume. This has contributed to the Soweto ADMD of 3.8 (Surtees 1993).

¹⁶ Gj is gigajoule a measure of energy which is equivalent to approximately 20kgs of LPG.

(source: Boyes 1994)

In the case of a low usage scenario, the cost recovery of the network would be adding more than a rand per kilogram of gas used.

8.2 Household Consumption

The poorer a household becomes, the higher is the proportion of income which is designated to covering the costs of providing energy services. Such an observation could imply that energy consumption is inelastic with respect to income for those who are in the lowest income categories. This is an indicator of energy services being a basic need.

It is the poor who have the greatest incentive to save reduce expenditure and therefore energy. This is substantiated by documentation of energy use practices which suggest that the poor are efficient users of energy services within the constraints of lack of access to efficient fuels and appliances, and poor thermal performances of their dwellings.

However, the appliances and fuels which are accessible to the poor are limited because of the barrier that limited access to credit provides. It is therefore unlikely that appliances which will be efficient in their energy transformation, will be accessible to the poor, unless the state or the utility intervene. Electricity, while becoming more affordable in first cost terms, is still only available to less than half of South Africa's households. Coal, candles, paraffin and wood are the remaining low access cost fuels of choice. But these are not normally the most efficient fuels to use and their use can result in much wastage of energy contributing to increasing life-cycle costs to those who can least afford them.

Another trend that is noticeable in recent studies of areas in the western Cape is that amongst households who have access to electricity, the lower the income the wider the range of fuels which are used. It is apparent that decisions are made by the poor which, if examined point to a keen feel of the energy service expenditures, and through a mix of fuels attempt to reach a least-(cash)-cost energy service solution, within the constraints mentioned above. In contrast, as the proportion of income utilised for energy services decreases (normally with increasing income), more electricity is used. This could be explained by considering the convenience of electricity; and therefore convenience becomes a discretionary expenditure.

8.3 Service Charge Structures

Please note that there are different ways of presenting this data, and that often distributors do not have a transparent cost build-up, other than to suggest that the tariff is related to bulk purchases with an additional amount which is considered as income to be used for the cross-subsidisation of municipal rates. In Cape Town this amount is typically 10% of the electricity sales. Appendix E includes data on the

domestic tariff structures of the major South African local governments and those utilised by Eskom.

8.4 Information Sources

Hendrik Barnard and David Ligoff of Eskom's pricing policy unit, the Association of Municipal Electrical Undertakings, and the United Municipal Executives are all bodies which would be able to provide information relating to the various tariff build-ups. Bruce Mountain of Eskom is managing a supply side database for the National Electricity Forum, which has captured data from around the country, and is available as a decision making tool of the National Electrification Forum.

9. Alternative Layout Concept

The least-cost energy plan for the national economy would include a mixture of fuels, of which reticulated electricity would be one. If this scenario holds, then electricity could be provided at low ADMD, Aerial Bundle Conductors and reticulated using labour based contracting above ground, in the road reserve. The poles would support streetlighting and closer to the ground, the telecommunications network. Simultaneously, trees should be planted to reduce the effect of aerial clutter, and provide shelter, summer shade and humidification. The variety of trees should be carefully selected to complement the thermal performance requirements of dwellings in the different climatic zones.

It is likely that solid fuels (wood, coal and smokeless coal), bottled gas and passive solar energy may provide the least-cost fuel option for the heavier thermal energy services. For the meantime reticulated gas should not be considered.

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Appendix A

fuel	cooking appliance	prices		cost of access		efficiency			accept	reference						
		minima	maxima	minima	maxima	reference MJ/unit	worst	best								
elec	hot plate	0.15	0.25	30	1500	3.6	55	75	65	1						
	oven	0.15	0.25	30	1500	3.6	55	75	65	1						
	micro-wave	0.15	0.25	30	1500	3.6	55	65		33						
	wick	1	1.62	0	0	37	20	35	30	1						
paraffin	primus	1	1.62	0	0	37	30	55	40	1						
gas	ring	1.8	3.17	50	3000	49	40	60	45	1						
	stove	1.8	3.17	50	3000	49	40	60		1						
wood	3-stone	0.07	0.26	0	0	17	13	15	15	1						
	stove	0.07	0.26	0	0	17	20	30	25	1						
dung	stove	0	0	0	0	12	11	11	11	5						
coal	stove	0.2	0.49	0	0	27	20	30		1.7						
	brazier	0.2	0.49	0	0	27	6	10	8	6						
low-smoke	stove	0.2	0.49	0	0	27	20	46		1.13						
space heating																
elec	radiant heater	0.15	0.25	30	1500	3.6	100	100		?						
	heat pump	0.15	0.25	30	1500	3.6	300	340		2						
	blower	0.15	0.25	30	1500	3.6	100	100		20						
	panel	0.15	0.25	30	1500	3.6	100	100		25						
paraffin	heater	1	1.62	0	0	37	45	100								
gas	primus	1	1.62	0	0	37	45	100		3						
	heater	1.8	3.17	50	3000	49	40	100		9						
wood	ring/stove	1.8	3.17	50	3000	49	40	100		9						
	open fire	0.07	0.26	0	0	17	85	100	inside	9.13						
	stove	0.07	0.26	0	0	17	20	60		9						
	fireplace	0.07	0.26	0	0	17	27	27		7.13						
dung	same as wood	0	0	0	0	12	20	60		13						
coal	stove	0.2	0.49	0	0	27	20	60		9						
	brazier	0.2	0.49	0	0	27	17	100	17	13						
low-smoke coal	stove	0.2	0.49	0	0	27	20	60		9						
water heating																
elec	heat pump	0.15	0.25	33	1500	3.6	250	340	320	36.11						
	geyser	0.15	0.25	33	1500	3.6	48	92	58	7						
	on line	0.15	0.25	33	1500	3.6	96	96	96	7						
paraffin	wick/pot	1	1.62	0	0	37	20	35	30	1						
gas	primus/pot	1	1.62	0	0	37	30	55	40	1						
	ring/pot	1.8	3.17	50	3000	49	40	60	45	1						
wood	geyser	1.8	3.17	50	3000	49	75	92		34.16						
	pot/fire	0.07	0.26	0	0	17	13	15		1						
dung	pot/stove	0.07	0.26	0	0	17	20	30		1						
	pot	0	0	0	0	12	11	11		5						
solar	SWH	0	0	0	0	1	1000	1000		27						
mix	Solar/electric	0.15	0.25	33	1500	3.6	160	307		27						
coal	stove(jacket/pot)	0.2	0.49	0	0	27	20	46		1.13						
low-smoke	stove(jacket/pot)	0.2	0.49	0	0	27	20	46		1.13						
lighting																
elec	incandescent	efficiency		lumens		watts/1000lu		hrs/1000 hrs								
		lumens/watt		max	min	max	min	max	min	max	min					
		0.15	0.25	33	300	3.6	10	10	400	400	8.8	100.00	100.00	2.50	2.50	
	0.15	0.25	33	300	3.6	11	11	660	660	8.8	90.91	90.91	1.52	1.52		
	0.15	0.25	33	300	3.6	18	18	1750	1750	8.8	55.56	55.56	0.57	0.57		
	fluorescent	0.15	0.25	33	300	3.6	50	50	600	600	8.8	20.00	20.00	1.67	1.67	
		0.15	0.25	33	300	3.6	62	62	1250	1250	8.8	16.13	16.13	0.80	0.80	
		0.15	0.25	33	300	3.6	75	75	3000	3000	8.8	13.33	13.33	0.33	0.33	
	press. vapour	0.15	0.25	33	300	3.6	40	40	4000	4000	8.8	25.00	25.00	0.25	0.25	
		0.15	0.25	33	300	3.6	100	100	25000	25000	8.8	10.00	10.00	0.04	0.04	
		0.15	0.25	33	300	3.6	37.3	41.8			40	26.81	20.00			
	PV (< R 1500)	0	0	1672	1490	3.6	37.3	41.8	2508	2238	40.41	26.81	20.00	0.45	0.40	
	PV (Eskom Raps tariff)	0.88	1.48	200	200	3.6	37.3	41.8	2508	2238	40.41	26.81	20.00	0.45	0.40	
	paraffin	Hurricane	1	1.62	0	0	37	0.3	0.3	80	20	7.8	3333.33	3333.33	50.00	12.50
	gas	Pressure	1	1.62	0	0	37	1.2	1.2	1500	500	7.8	833.33	833.33	2.00	0.67
Pressure		1.8	3.17	50	100	49	1	1	200	300	7.8	1000.00	1000.00	3.33	5.00	
candles	Candles	0.09	0.42	0	0	3.45	0.2	0.2	30	10	7.8	5000.00	5000.00	100.00	33.33	
2000 litre fridge																
elec	mains	0.15	0.25	33	1500	3.6				8						
	DC-RAPS	2.5	22.2	1500	2000	3.6				8						
	AC-RAPS									8						
paraffin	paraffin	1	1.62	0	0	37				8						
gas	gas	1.8	3.17	50	3000	49				8						

- 1: Leach and Gowen
- 2: Greyvenstein - Enerconomy
- 3: Inferred from 1
- 4: Enenek
- 5: Kashkari (1975) in Jas Gill (1987)
- 6: McGranahan et al (1980), Smih (1981) and Stanford (undated) in Gill
- 7: Beute (1993)
- 8: RAPS manual 21
- 9: Horsfall in New Ground
- 10: Technheat 8/06/93

- 11: Cape Energy (Hans Pruter) 8/06/93
- 12: Bennett 1977:1223-5
- 13: Allison & Dutkiewicz in Viljoen 1993:11
- 14: Citigas direct communication
- 15: Viljoen 1993:13
- 16: Easigas
- 17: Crossroads gas centre
- 18: Ant Williams
- 19: Eskom electrification
- 20: Heater blower specs

Appendix A

fuel	cooking appliance	price max	price min	reference	expected serv hours	hrs/day max	years low	hrs/day min	years high	10MJ			operating		
										Units per hou vol.or mass	min R/10MJ	max R/10MJ	min R/year	max R/year	
elec	hot plate	200	50	19	4000	4	2.74	1	10.96	1	0.56	1.26	54.75	365.00	
	oven	1800	800	13.	8000	4	5.48	1	21.92	2	0.56	1.26	109.50	730.00	
	micro-wave	1600	800	33.33	10000	2	13.70	0.5	54.79	1	0.64	1.26	35.59	237.25	
paraffin	wick	43	25	13.	2190	8	0.75	1	6.00	0.13	0.77	2.19	47.45	614.95	
	primus	46	25	13.	1095	8	0.38	1	4.00	0.13	0.49	1.46	35.59	614.95	
gas	ring	119	89.5	16.17	4380	4	3.00	1	12.00	0.19	0.61	1.62	124.83	879.36	
	stove	1000	690	13	8000	4	5.48	1	21.92	0.19	0.61	1.62	124.83	879.36	
wood	3-stone	0	0	?	?	4	13.70	1	54.79	2.6	0.27	1.18	0.00	0.00	
	stove	540	200	13.18	8000	4	5.48	1	21.92	2.6	0.14	0.76	66.43	986.96	
dung	stove	540	200	13.18	8000	4	5.48	1	21.92	2.6	0.00	0.00	0.00	0.00	
	stove	3000	540	13	20000	8	6.85	2	27.40	4	0.25	0.91	584.00	5723.20	
coal	brazier	10	10	13	1000	4	0.68	2	1.37	4	0.74	3.02	584.00	2861.60	
	stove	3000	540	13	20000	8	6.85	2	27.40	3.2	0.16	0.91	467.20	4578.56	
space heating															
elec	radiant heater	200	100	?	5000	4	3.42	1	13.70	1.4	0.42	0.69	76.65	511.00	
	heat pump	8000	6000	23	130000	24	14.84	24	14.84	12	0.12	0.23	3942.00	6570.00	
	blower	129	100	?	5000	4	3.42	1	13.70	2	0.42	0.69	109.50	730.00	
paraffin	panel	89	89	25	20000	6	9.13	2	27.40	0.65	0.42	0.69	71.18	355.88	
	heater	150	43	7.13	8000	4	5.48	1	10.00	0.13	0.27	0.97	104.00	307.48	
gas	primus	46	25	13.	1095	8	0.38	1	3.00	0.13	0.27	0.97	47.45	614.95	
	heater	570	89	14	4380	4	3.00	1	12.00	0.19	0.37	1.62	124.83	879.36	
wood	ring/stove	119	89	16.17	4380	4	3.00	1	12.00	0.19	0.37	1.62	124.83	879.36	
	open fire	0	0	?	20000	4	13.70	1	54.79	2.6	0.04	0.18	66.43	986.96	
dung	stove	540	200	13.18	8000	4	5.48	1	21.92	2.6	0.07	0.76	66.43	986.96	
	fireplace	4600	0	22.	20000	4	13.70	1	54.79	2.6	0.15	0.57	66.43	986.96	
coal	same as wood	540	200	13.18	8000	4	5.48	1	21.92	2.6	0.00	0.00	0.00	0.00	
	stove	3000	540	13	20000	8	6.85	1	54.79	4	0.12	0.91	292.00	5723.20	
low-smoke coal	brazier	10	10	13	1000	4	0.68	1	2.74	4	0.07	1.07	292.00	2861.60	
	stove	3000	540	13	20000	8	6.85	1	54.79	3.2	0.12	0.91	233.60	4578.56	
water heating															
elec	heat pump	10000	6000	10	21900	15	4.00	2	30.00	1	0.12	0.28	109.5	1368.75	
	geyser	2000	2000	?	10000	2	13.70	0.5	54.79	3	0.87	1.45	82.125	547.5	
paraffin	on line	500	500	?	5000	0.5	27.40	0.5	27.40	9	0.43	0.72	246.375	410.625	
	wick/pot	43	25	13.	2190	2	3.00	0.5	12.00	0.13	0.77	2.19	23.725	153.738	
gas	primus/pot	46	25	13.	1000	2	1.37	0.5	5.48	0.13	0.49	1.46	23.725	153.738	
	ring/pot	119	89.5	16.17	4380	1	12.00	0.5	24.00	0.19	0.61	1.62	62.415	219.8395	
wood	geyser	1150	1150	16	10000	1	27.40	0.25	109.59	0.19	0.40	0.86	31.2075	219.8395	
	pot/fire	0	0	?	1	1	0.00	1	0.00	2.6	0.27	1.18	66.43	246.74	
dung	pot/stove	540	200	13.18	8000	1	21.92	1	21.92	2.6	0.14	0.76	66.43	246.74	
	pot	540	200	13.18	8000	1	21.92	1	21.92	2.6	0.00	0.00	0	0	
solar	SWH	1750	1090	37	43800	8	8.00	6	15.00	0	0.00	0.00	0	0	
	Solar/electric	6135	2450	38.39	43800	8	8.00	6	15.00	0	0.14	0.43	438	1368.75	
coal	stove(jacket/pot)	3000	540	13	20000	2	27.40	1	54.79	4	0.16	0.91	292	1430.8	
	stove(jacket/pot)	3000	540	13	20000	2	27.40	1	54.79	3.2	0.16	0.91	365	1788.5	
lighting															
elec	incandescent	3	1.99	28.29	1000	6	0.46	1	2.74	2777.77778	1.50	2.50	2.19	21.90	
		3.5	2	28.29	1000	6	0.46	1	2.74	3055.55556	1.36	2.27	3.29	32.85	
		4	2	28.29	1000	6	0.46	1	2.74	5000	0.83	1.39	5.48	54.75	
	fluorescent	45	25	28.29	5000	6	2.28	1	13.70	13888.88889	0.30	0.50	0.66	6.57	
		45	25	28.29	5000	6	2.28	1	13.70	17222.22222	0.24	0.40	1.10	10.95	
		45	25	28.29	5000	6	2.28	1	13.70	20833.33333	0.20	0.33	2.19	21.90	
	press. vapour	100	100	29	20000	12	4.57	6	9.13	11111.11111	0.38	0.63	32.85	109.50	
		100	100	29	20000	12	4.57	6	9.13	27777.77778	0.15	0.25	82.13	273.75	
		0	0	40	5000	4	3.42	1	13.70	10986.11111	0.00	0.00	0.00	0.00	
	paraffin	PV (c R 1500)	0	0	41	5000	4	3.42	1	13.70	10986.11111	2.11	3.97	11.56	77.79
		Hurricane	42	15.55	0	4000	4	2.74	1	10.96	8.10810811	32.43	52.54	0.97	6.27
	gas	Pressure	155	155	30	4000	4	2.74	1	10.96	32.4324324	8.11	13.14	2.76	17.91
		Pressure	37	20	31.2	4000	4	2.74	1	10.96	20.4081633	13.22	23.29	1.01	7.14
	candles	Candles	0	0	12	10	4	0.01	2	0.01	57.9710145	46.96	219.13	22.67	211.55
		200 lire tridge													
elec	mains														
	DC-RAPS														
paraffin	AC-RAPS														
	paraffin														
gas	gas														

- 21: Uken and Beute 1991
- 22: Suburban Hardware Mowbray 1993
- 23: Hans Pruter, Cape Energy 1993
- 24: De Longhi, VO2 Fan heaters 1993
- 25: Eco-heat panels 1993
- 26:
- 27: Hazel Hall, Acorn 1993
- 28: Eurolighting 1992
- 30: Camp and Clinb 1993
- 31: Easigas 1993

- 32: Morris 1993
- 33: KIC 1993
- 34: Turiel 1986
- 35: Anneke 1993
- 36: Coetzee 1990
- 37: Prontek 1993
- 38: Atlantic Solar 1993
- 39: Mikado 1993
- 40: Cowan 1993

Appendix A

fuel	cooking appliance	Energy	LCC	LCC	LCC	energy	LCC	LCC	
		MJ/day minima	R/10MJ minima	R/month minima	amon' R/day maxima	MJ/day maxima	R/10MJ maxima	R/month maxima	
elec	hot plate	2.70	0.60	3.78	1.57	7.92	1.98	12.49	
	oven	5.40	0.66	4.18	3.01	15.84	1.90	11.95	
	micro-wave	1.52	0.70	4.41	0.98	5.15	1.90	11.96	
paraffin	wick	1.68	0.83	5.24	1.84	7.70	2.39	15.07	
	primus	2.65	0.43	2.70	2.03	11.54	1.76	11.05	
gas	ring	5.59	0.65	4.07	3.21	14.90	2.16	13.57	
	stove	5.59	0.70	4.44	3.26	14.90	2.19	13.78	
wood	3-stone	6.63	0.00	0.00	0.00	22.98	0.00	0.00	
	stove	13.26	0.15	0.93	2.95	35.36	0.83	5.24	
dung	stove	3.43	0.04	0.26	0.24	13.73	0.18	1.11	
coal	stove	64.80	0.25	1.58	16.72	172.80	0.97	6.09	
	brazier	21.60	0.75	4.72	7.88	25.92	3.04	19.14	
low-smoke	stove	79.49	0.16	1.03	13.58	138.24	0.98	6.18	
space heating									
elec	radiant heater	5.04	0.45	24.34	1.86	20.16	0.92	49.99	
	heat pump	881.28	0.13	7.12	19.12	777.60	0.25	13.33	
	blower	7.20	0.44	23.81	2.41	28.80	0.84	45.27	
paraffin	panel	4.68	0.43	23.23	1.13	14.04	0.80	43.57	
	heater	4.81	0.61	33.16	0.91	8.66	1.05	56.92	
	primus	4.81	0.32	17.09	2.03	17.32	1.17	63.41	
gas	heater	9.31	0.39	21.01	3.60	14.90	2.42	131.07	
	ring/stove	9.31	0.39	21.01	3.21	14.90	2.16	116.81	
wood	open fire	44.20	0.04	2.23	2.70	150.28	0.18	9.75	
	stove	26.52	0.07	4.01	2.95	35.36	0.83	45.14	
	fireplace	11.93	0.15	8.26	3.37	47.74	0.71	38.22	
dung	same as wood	18.72	0.01	0.41	0.24	24.96	0.10	5.24	
coal	stove	64.80	0.12	6.74	16.72	172.80	0.97	52.42	
	brazier	108.00	0.07	4.06	7.88	73.44	1.07	58.15	
low-smoke coal	stove	51.84	0.12	6.75	13.58	138.24	0.98	53.23	
water heating									
elec	heat pump	24.48	0.22	14.08	10.11	135.00	0.75	47.13	
	geyser	4.97	0.49	31.08	1.79	10.37	1.72	108.57	
	on line	15.55	0.45	28.31	1.15	15.55	0.74	46.53	
paraffin	wick/pot	0.84	0.82	51.83	0.46	1.92	2.38	150.04	
	primus/pot	1.32	0.58	36.25	0.51	2.89	1.78	111.76	
gas	ring/pot	2.79	0.63	39.78	0.62	3.72	1.67	105.28	
	geyser	2.14	0.40	25.36	0.66	6.98	0.94	59.36	
wood	pot/fire	6.63	0.27	17.28	0.68	5.75	1.18	74.06	
	pot/stove	13.26	0.15	9.32	0.71	8.84	0.81	50.89	
dung	pot	3.43	0.04	2.63	0.04	3.43	0.11	7.09	
solar	SWH	8.36	0.17	10.42	0.50	8.36	0.60	37.81	
nix	Solar/electric	20.06	0.75	47.41	5.51	46.08	1.20	75.28	
coal	stove(jacket/pot)	49.68	0.16	10.21	4.07	43.20	0.94	59.26	
low-smoke	stove(jacket/pot)	62.10	0.16	10.19	5.05	54.00	0.93	58.83	
lighting									
		lumenhrs/dav	R/month		R/dav	lumenhours/dav	R/month		
		min	c/1000lmhrs			c/1000 lumenhours			
elec	incandescent	400.00	4.07	0.55	0.51	2400.00	21.24	19.19	
		660.00	2.92	0.73	0.54	3960.00	13.71	20.43	
		1800.00	1.40	0.95	0.61	10800.00	5.61	22.80	
	fluorescent	600.00	1.26	0.28	0.16	3600.00	4.46	6.04	
		1240.00	0.71	0.33	0.17	7440.00	2.32	6.49	
		3000.00	0.39	0.44	0.20	18000.00	1.13	7.62	
	press. vapour	24000.00	0.49	4.41	0.40	48000.00	0.84	15.15	
		150000.00	0.17	9.49	0.85	300000.00	0.28	32.08	
		1342.80	16.00	30.11	1.16	6019.20	28.00	43.65	
paraffin	PV (Eskom Raps tarif)	8952.00	8.15	27.47	0.92	10032.00	9.17	34.62	
		8.18	69.29	0.21	0.06	32.70	175.56	2.16	
		93.40	40.27	1.42	0.20	373.60	52.87	7.43	
gas	Pressure	21.00	49.90	0.39	0.08	84.00	95.64	3.02	
		132.25	46.96	2.34	0.58	264.50	219.13	21.81	
candles	200 litre fridge	R/dav							
			0.6	22.58				22.58	
			2.4	90.32				90.32	
paraffin	DC-RAPS		5	188.16				188.16	
			2	75.26				75.26	
gas	AC-RAPS		1.82	68.49				68.49	

4 kVA ADMD
36 du/ha
285.00 erven

Underground supply

APPENDIX J

	unit	quantity	unit rate	labour rate	
Medium/High Voltage (HV) reticulation					
excavations		1	800	0.00	15.00
slabs		1	800	2.00	2.00
warning tape		1	800	0.50	0.00
50 Cu core pex cable		1	800	65.00	2.50
terminations		1	9	800.00	200.00
200 kVA minisubstation		1	6	30000.00	3000.00
sub-total			241200.00	35400.00	276600.00
per erf			846.32	124.21	970.53
Preliminary and General costs					
total prelim & general					55000.00
per erf					192.98
Low Voltage (LV) reticulation					
excavations		1	2787	0.00	10.00
50 Cu 4 core PVC-SWA-PVC		1	2787	38.00	1.50
LV terminations		1	48	0.00	100.00
PV earth cond 50 mm2		1	576	8.93	0.30
1.8m earth electrode		1	48	15.70	5.04
3.5m galvanised pipe		1	48	17.25	6.40
stubbys		1	48	1500.00	200.00
sub-total			184631.28	47172.42	231803.70
per erf			647.83	165.52	813.35
Street lighting					
luminaires, outreach etc.		1	50	150.00	50.00
terminations		1	100	0.00	20.00
Illumodac		1	1000	4.50	0.50
poles		1	50	235.00	50.00
sub-total			23750.00	7500.00	31250.00
per erf			83.33	26.32	109.65
Service connection					
ready boards		1	285	180.00	50.00
airdac		1	7125	4.25	1.00
excavations		1	7125	0.00	10.00
meters		1	285	300.00	150.00
terminations		1	570	0.00	35.00
sub total			167651.25	155325.00	322406.25
per erf			588.25	545.00	1131.25
Summary table					
			materials	labour	total
MV/HVreticulation					
LV reticulation					
service connections					
sub-total			593482.53	237897.42	831379.95
sub-total per erf			2082.39	834.73	2917.12
streetlighting					
prelim & general					
sub-total			78750.00	7500.00	86250.00
sub-total per erf			276.32	26.32	302.63
total			672232.53	245397.42	917629.95
total per erf			2358.71	861.04	3219.75

4 kVA ADMD 108 du/ha 860.00 erven		Underground supply			
	unit	quantity	unit rate	labour rate	
Medium/High Voltage (HV) reticulation					
excavations	1	1760	0.00	15.00	26400.00
slabs	1	1760	2.00	2.00	7040.00
warning tape	1	1760	0.50	0.00	880.00
50 Cu core pex cable	1	1760	85.00	2.50	154000.00
terminations	1	36	800.00	200.00	36000.00
200 kVA minisubstation	1	24	30000.00	3000.00	792000.00
sub-total			902800.00	113520.00	1016320.00
per erf			1049.77	132.00	1181.77
Preliminary and General costs					
total prelim & general					75000.00
per erf					87.21
Low Voltage (LV) reticulation					
excavations	1	1200	0.00	10.00	12000.00
50 Cu 4 core PVC-SWA-PVC	1	1200	55.00	1.50	67800.00
LV terminations	1	96	0.00	100.00	9600.00
PV earth cond 50 mm2	1	1152	8.93	0.30	10632.96
1.8m earth electrode	1	96	15.70	5.04	1991.04
3.5m galvanised pipe	1	96	17.25	6.40	2270.40
stubbys	1	80	1500.00	200.00	136000.00
sub-total			199450.56	40843.84	240294.40
per erf			231.92	47.49	279.41
Street lighting					
luminaires, outreach etc.	1	50	150.00	50.00	10000.00
terminations	1	100	0.00	20.00	2000.00
Illumodac	1	1000	4.50	0.50	5000.00
poles	1	50	142.00	200.00	17100.00
sub-total			19100.00	15000.00	34100.00
per erf			22.21	17.44	39.65
Service connection					
ready boards	1	860	180.00	50.00	197800.00
airdac	1	25800	4.25	1.00	135450.00
excavations	1	25800	0.00	10.00	258000.00
meters	1	860	300.00	150.00	387000.00
terminations	1	1720	0.00	35.00	60200.00
sub total			524170.00	516000.00	1038450.00
per erf			609.50	600.00	1207.50
Summary table					
		materials	labour	total	
MV/HV reticulation					
LV reticulation					
service connections					
sub-total		1626420.56	670363.84	2296784.40	
sub-total per erf		1891.19	779.49	2670.68	
street lighting					
prelim & general					
sub-total		94100.00	15000.00	109100.00	
sub-total per erf		109.42	17.44	126.86	
total		1720520.56	685363.84	2405884.40	
total per erf		2000.61	796.93	2797.54	

1 kVA ADMD
36 du/ha
285.00 erven

Underground supply

	unit	quantity	unit rate	labour rate		
Medium/High Voltage (HV) reticulation						
excavations		1	405	0.00	15.00	6075.00
slabs		1	405	2.00	2.00	1620.00
warning tape		1	405	0.50	0.00	202.50
50 Cu 4 core pex cable		1	405	65.00	2.50	27337.50
terminations		1	3	800.00	200.00	3000.00
200 kVA minisubstation		1	2	30000.00	3000.00	66000.00
sub-total				89737.50	14497.50	104235.00
per erf				314.87	50.87	365.74

Preliminary and General costs

total prelim & general						55000.00
per erf						192.98

Low Voltage (LV) reticulation

excavations		1	2787	0.00	10.00	27870.00
50 Cu core PVC-SWA-PVC		1	2787	38.00	1.50	110086.50
LV terminations		1	48	0.00	100.00	4800.00
PV earth cond 50 mm2		1	576	8.93	0.30	5316.48
1.8m earth electrode		1	48	15.70	5.04	995.52
3.5m galvanised pipe		1	48	17.25	6.40	1135.20
stubbys		1	48	1500.00	200.00	81600.00
sub-total				184631.28	47172.42	231803.70
per erf				647.83	165.52	813.35

Street lighting

luminaires, outreach etc.		1	50	150.00	50.00	10000.00
terminations		1	100	0.00	20.00	2000.00
Illumodac		1	1000	4.50	0.50	5000.00
poles		1	50	235.00	50.00	14250.00
sub-total				23750.00	7500.00	31250.00
per erf				83.33	26.32	109.65

Service connection

ready boards		1	285	180.00	50.00	65550.00
airdac		1	7125	4.25	1.00	37406.25
excavations		1	7125	0.00	10.00	71250.00
meters		1	285	300.00	150.00	128250.00
terminations		1	570	0.00	35.00	19950.00
sub total				167651.25	155325.00	322406.25
per erf				588.25	545.00	1131.25

Summary table

	materials	labour	total
MV/HV reticulation			
LV reticulation			
service connections			
sub-total	442020.03	216994.92	659014.95
sub-total per erf	1550.95	761.39	2312.33
streetlighting			
prelim & general			
sub-total	78750.00	7500.00	86250.00
sub-total per erf	276.32	26.32	302.63
total	520770.03	224494.92	745264.95
total per erf	1827.26	787.70	2614.96

1kVA ADMD 108.00 du/ha 860.00 erven		Overhead supply			
Unit	Quantity	unit rate	labour rate	amount (Rands)	
Medium/High Voltage (HV) reticulation					
11m poles inc fittings	1	35	535.00	235.00	26950.00
MV stays	1	20	180.00	50.00	4600.00
MV strut poles	1	9	250.00	60.00	2790.00
ACSR mink	1	4900	2.45	0.50	14455.00
Link sets	1	7	740.00	180.00	6440.00
100 kVA CSP transformer	1	0	10545.00	68.00	0.00
200 kVA CSP Transformer	1	6	18000.00	68.00	108408.00
315 kVA Peanut	1	0	23800.00	68.00	0.00
sub-total			49829.50	13883.00	163643.00
per erf			57.94	16.14	190.28
Preliminary and General costs					
sub-total prelim & general					75000.00
per erf					
Low Voltage (LV) reticulation					
9 m poles	1	37	142.50	200.00	12672.50
stay assemblies	1	24	132.45	60.00	4618.80
strut assemblies	1	0	142.50	78.00	0.00
ABC 3*120+70+25mm2	1	0	24.00	8.76	0.00
ABC 3*95+54.6+25mm2	1	1200	18.00	7.85	31020.00
ABC 3*70+54.6+25mm2	1	600	13.90	3.80	10620.00
ABC 3*35+54.6 25mm2	1	2232	10.05	3.02	29172.24
strain assembly	1	24	36.00	10.51	1116.24
suspension assembly	1	40	24.00	6.12	1204.80
bolts for str & susp ass.	1	64	5.00	5.00	640.00
120-35/95-35 IPC's	1		14.00	3.21	0.00
95-35/70-35 IPC's	1	185	9.98	2.05	2225.55
ABC end terminations	1	96	19.00	5.10	2313.60
PVC Earth cond 50 mm2	1	1152	8.93	0.30	10632.96
1.8m earth electrode	1	96	15.70	5.04	1991.04
3.5 galvansied pipe	1	96	17.25	6.40	2270.40
stainless steel straps	1	1	450.00	400.00	850.00
service protection boxes	1	860	174.00	31.00	176300.00
sub-total			230177.76	57470.37	287648.13
per erf			267.65	66.83	334.47
Street lighting					
luminaires, outreach etc.	1	50	150.00	50.00	10000.00
IPC's	1	100	8.00	1.50	950.00
llumodac	1	100	4.50	0.50	500.00
sub-total			8750.00	2700.00	11450.00
per erf			10.17	3.14	13.31
Service connection					
ready boards	1	860	180.00	50.00	197800.00
airdac	1	24080	4.25	1.00	126420.00
airdac clamps	1	1720	19.50	2.00	36980.00
meters	1	860	300.00	150.00	387000.00
sub-total			548680.00	199520.00	748200.00
per erf			638.00	232.00	870.00
Summary Table					
		materials	labour	total	
MV/HVreticulation					
LV reticulation					
service connections					
sub-total		828687.26	270873.37	1099560.63	
sub-total per erf		963.59	314.97	1278.56	
streetlighting					
prelim & general					
sub-total		83750.00	2700.00	86450.00	
sub-total per erf		97.38	3.14	100.52	
total		912437.26	273573.37	1186010.63	
total per erf		1060.97	318.11	1379.08	

1 kVA	ADMD	Overhead supply			
	36.00 du/ha 285.00 erven				
	Unit	Quantity	unit rate	labour rate	amount (Rands)
Medium/high voltage reticulation					
11m poles inc fittings	1	11	535.00	235.00	8470.00
MV stays	1	7	180.00	50.00	1610.00
MV strut poles	1	6	250.00	60.00	1860.00
ACSR mink	1	1210	2.45	0.50	3569.50
Link sets	1	3	740.00	180.00	2760.00
100 kVA CSP transformer	1	0	10545.00	68.00	0.00
200 kVA CSP Transformer	1	2	18000.00	68.00	36136.00
315 kVA Peanut	1	0	23800.00	68.00	0.00
sub-total			49829.50	4576.00	54405.50
per erf			174.84	16.06	190.90
Preliminary and General costs					
sub-total prelim & general					50000.00
per erf					
Low voltage reticulation					
9 m poles	1	51	142.50	200.00	17467.50
stay assemblies	1	30	132.45	60.00	5773.50
strut assemblies	1	6	142.50	78.00	1323.00
ABC 3*120+70+25mm2	1	0	24.00	8.76	0.00
ABC 3*95+54.6+25mm2	1	0	18.00	7.85	0.00
ABC 3*70+54.6+25mm2	1	2787	13.90	3.80	49329.90
ABC 3*35+54.6 25mm2	1	0	10.05	3.02	0.00
strain assembly	1	45	36.00	10.51	2092.95
suspension assembly	1	28	24.00	6.12	843.36
bolts for str & susp ass.	1	73	5.00	5.00	730.00
120-35/95-35 IPC's	1		14.00	3.21	0.00
95-35/70-35 IPC's	1	255	9.98	2.05	3067.65
ABC end terminations	1	41	19.00	5.10	988.10
PVC Earth cond 50 mm2	1	492	8.93	0.30	4541.16
1.8m earth electrode	1	41	15.70	5.04	850.34
3.5 galvansied pipe	1	41	17.25	6.40	969.65
stainless steel straps	1	1	600.00	400.00	1000.00
service protection boxes	1	285	174.00	31.00	58425.00
sub-total			112750.71	34651.40	147402.11
per erf			395.62	121.58	517.20
Street lighting					
luminaires, outreach etc.	1	50	150.00	50.00	10000.00
IPC's	1	100	8.00	1.50	950.00
Illumodac	1	100	4.50	0.50	500.00
sub-total			8750.00	2700.00	11450.00
per erf			30.70	9.47	40.18
Service connection					
ready boards	1	285	180.00	50.00	65550.00
airdac	1	7125	4.25	1.00	37406.25
airdac clamps	1	570	19.50	2.00	12255.00
meters	1	285	300.00	150.00	128250.00
sub-total			178196.25	65265.00	243461.25
per erf			625.25	229.00	854.25
Summary Table					
		materials	labour	total	
MV/HV reticulation					
LV reticulation					
service connections					
sub-total		340776.46	104492.40	445268.86	
sub-total per erf		1195.71	366.64	1562.35	
streetlighting					
prelim & general					
sub-total		58750.00	2700.00	61450.00	
sub-total per erf		206.14	9.47	215.61	
total		399526.46	107192.40	506718.86	
total per erf		1401.85	376.11	1777.96	

4kVA ADMD 108 du/ha 860.00 erven		Overhead supply			
Unit	Quantity	unit rate	labour rate	amount (Rands)	
Medium/High Voltage (HV) reticulation					
11m poles inc fittings	1	46	535.00	235.00	35420.00
MV stays	1	33	180.00	50.00	7590.00
MV strut poles	1	9	250.00	60.00	2790.00
ACSR mink	1	5280	2.45	0.50	15576.00
Link sets	1	25	740.00	180.00	23000.00
100 kVA CSP transformer	1	0	10545.00	68.00	0.00
200 kVA CSP Transformer	1	24	18000.00	68.00	433632.00
315 kVA Peanut	1	0	23800.00	68.00	0.00
sub-total			496236.00	21772.00	518008.00
per erf			577.02	25.32	602.33
Preliminary and General costs					
sub-total prelim & general					75000.00
per erf					
Low Voltage (LV) reticulation					
9 m poles	1	37	142.50	200.00	12672.50
stay assemblies	1	24	132.45	60.00	4618.80
strut assemblies	1	0	142.50	78.00	0.00
ABC 3*120+70+25mm2	1	0	24.00	8.76	0.00
ABC 3*95+54.6+25mm2	1	1200	18.00	7.85	31020.00
ABC 3*70+54.6+25mm2	1	600	13.90	3.80	10620.00
ABC 3*35+54.6 25mm2	1	2232	10.05	3.02	29172.24
strain assembly	1	96	36.00	10.51	4464.96
suspension assembly	1	40	24.00	6.12	1204.80
bolts for str & susp ass.	1	136	5.00	5.00	1360.00
120-35/95-35 IPC's	1		14.00	3.21	0.00
95-35/70-35 IPC's	1	185	9.98	2.05	2225.55
ABC end terminations	1	96	19.00	5.10	2313.60
PVC Earth cond 50 mm2	1	1152	8.93	0.30	10632.96
1.8m earth electrode	1	96	15.70	5.04	1991.04
3.5 galvansied pipe	1	96	17.25	6.40	2270.40
stainless steel straps	1	1	450.00	400.00	850.00
service protection boxes	1	860	174.00	31.00	176300.00
sub-total			233129.76	58587.09	291716.85
per erf			271.08	68.12	339.21
Street lighting					
luminaires, outreach etc.	1	50	150.00	50.00	10000.00
IPC's	1	100	8.00	1.50	950.00
llumodac	1	100	4.50	0.50	500.00
sub-total			8750.00	2700.00	11450.00
per erf			10.17	3.14	13.31
Service connection					
ready boards	1	860	180.00	50.00	197800.00
airdac	1	24080	4.25	1.00	126420.00
airdac clamps	1	1720	19.50	2.00	36980.00
meters	1	860	300.00	150.00	387000.00
sub-total			548680.00	199520.00	748200.00
per erf			638.00	232.00	870.00
Summary Table					
		materials	labour	total	
MV/HV reticulation					
LV reticulation					
service connections					
sub-total		1278045.76	279879.09	1557924.85	
sub-total per erf		1486.10	325.44	1811.54	
streetlighting					
prelim & general					
sub-total		83750.00	2700.00	86450.00	
sub-total per erf		97.38	3.14	100.52	
total		1361795.76	282579.09	1644374.85	
total per erf		1583.48	328.58	1912.06	

4 kVA ADMD 36.00 du/ha 285.00 erven		Overhead supply				
	Unit	Quantity	unit rate	labour rate	amount (Rands)	
Medium/High Voltage (HV) reticulation						
11m poles inc fittings	1	19	535.00	235.00	14630.00	
MV stays	1	15	180.00	50.00	3450.00	
MV strut poles	1	8	250.00	60.00	2480.00	
ACSR mink	1	2370	2.45	0.50	6991.50	
Link sets	1	7	740.00	180.00	6440.00	
100 kVA CSP transformer	1	0	10545.00	68.00	0.00	
200 kVA CSP Transformer	1	6	18000.00	68.00	108408.00	
315 kVA Peanut	1	0	23800.00	68.00	0.00	
sub-total			133851.50	8548.00	142399.50	
per erf			469.65	29.99	499.65	
Preliminary and General costs						
sub-total prelim & general					50000.00	
per erf						
Low Voltage (LV) reticulation						
9 m poles	1	51	142.50	200.00	17467.50	
stay assemblies	1	30	132.45	60.00	5773.50	
strut assemblies	1	6	142.50	78.00	1323.00	
ABC 3*120+70+25mm2	1	0	24.00	8.76	0.00	
ABC 3*95+54.6+25mm2	1	0	18.00	7.85	0.00	
ABC 3*70+54.6+25mm2	1	2787	13.90	3.80	49329.90	
ABC 3*35+54.6 25mm2	1	0	10.05	3.02	0.00	
strain assembly	1	45	36.00	10.51	2092.95	
suspension assembly	1	28	24.00	6.12	843.36	
bolts for str & susp ass.	1	73	5.00	5.00	730.00	
120-35/95-35 IPC's	1		14.00	3.21	0.00	
95-35/70-35 IPC's	1	255	9.98	2.05	3067.65	
ABC end terminations	1	41	19.00	5.10	988.10	
PVC Earth cond 50 mm2	1	492	8.93	0.30	4541.16	
1.8m earth electrode	1	41	15.70	5.04	850.34	
3.5 galvansied pipe	1	41	17.25	6.40	969.65	
stainless steel straps	1	1	600.00	400.00	1000.00	
service protection boxes	1	285	174.00	31.00	58425.00	
sub-total			112750.71	34651.40	147402.11	
per erf			395.62	121.58	517.20	
Street lighting						
luminaires, outreach etc.	1	50	150.00	50.00	10000.00	
IPC's	1	100	8.00	1.50	950.00	
llumodac	1	100	4.50	0.50	500.00	
sub-total			8750.00	2700.00	11450.00	
per erf			30.70	9.47	40.18	
Service connection						
ready boards	1	285	180.00	50.00	65550.00	
airdac	1	7125	4.25	1.00	37406.25	
airdac clamps	1	570	19.50	2.00	12255.00	
meters	1	285	300.00	150.00	128250.00	
sub-total			178196.25	65265.00	243461.25	
per erf			625.25	229.00	854.25	
Summary Table						
			materials	labour	total	
MV/HV reticulation						
LV reticulation						
service connections						
sub-total			424798.46	108464.40	533262.86	
sub-total per erf			1490.52	380.58	1871.10	
streetlighting						
prelim & general						
sub-total			58750.00	2700.00	61450.00	
sub-total per erf			206.14	9.47	215.61	
total			483548.46	111164.40	594712.86	
total per erf			1696.66	390.05	2086.71	

1 kVA ADMD 108 du/ha 860.00 erven		Underground supply			
	unit	quantity	unit rate	labour rate	
Medium/High Voltage (HV) reticulation					
excavations	1	1650	0.00	15.00	24750.00
slabs	1	1650	2.00	2.00	6600.00
warning tape	1	1650	0.50	0.00	825.00
50 Cu core pex cable	1	1650	85.00	2.50	144375.00
terminations	1	9	800.00	200.00	9000.00
200 kVA minisubstation	1	6	30000.00	3000.00	198000.00
sub-total			331575.00	51975.00	383550.00
per erf			385.55	60.44	445.99
Preliminary and General costs					
total prelim & general					75000.00
per erf					87.21
Low Voltage (LV) reticulation					
excavations	1	203	0.00	10.00	2030.00
50 Cu 4 core PVC-SWA-PVC	1	203	55.00	1.50	11469.50
LV terminations	1	96	0.00	100.00	9600.00
PV earth cond 50 mm2	1	1152	8.93	0.30	10632.96
1.8m earth electrode	1	96	15.70	5.04	1991.04
3.5m galvanised pipe	1	96	17.25	6.40	2270.40
stubbys	1	80	1500.00	200.00	136000.00
sub-total			144615.56	29378.34	173993.90
per erf			168.16	34.16	202.32
Street lighting					
luminaires, outreach etc.	1	50	150.00	50.00	10000.00
terminations	1	100	0.00	20.00	2000.00
Illumodac	1	1000	4.50	0.50	5000.00
poles	1	50	142.00	200.00	17100.00
sub-total			19100.00	15000.00	34100.00
per erf			22.21	17.44	39.65
Service connection					
ready boards	1	860	180.00	50.00	197800.00
airdac	1	25800	4.25	1.00	135450.00
excavations	1	25800	0.00	10.00	258000.00
meters	1	860	300.00	150.00	387000.00
terminations	1	1720	0.00	35.00	60200.00
sub total			524170.00	516000.00	1038450.00
per erf			609.50	600.00	1207.50
Summary table					
		materials	labour	total	
MV/HV reticulation					
LV reticulation					
service connections					
sub-total		1000360.56	597353.34	1597713.90	
sub-total per erf		1163.21	694.60	1857.81	
streetlighting					
prelim & general					
sub-total		94100.00	15000.00	109100.00	
sub-total per erf		109.42	17.44	126.86	
total		1094460.56	612353.34	1706813.90	
total per erf		1272.63	712.04	1984.67	

Appendix C: Gas reticulation costs.

Estimates are based on a greenfield site costed over 1200 dwelling units, and is installed when other municipal services are installed.

Estimates are for steel, High Density Poly Ethylene (HDPE) and Polyflow plastic pipes, and are considered to be +/-20% accurate.

dwelling units per hectare	35	35	35	22	22	22	9.2	9.2	9.2	2
	steel	HDPE	Polyflow	steel	HDPE	Polyflow	steel	HDPE	Polyflow	Steel (light industry)
1 Direct Field Costs (DFC)										
earthworks and civil	279380	279380	279380	399550	399550	399550	549000	549000	549000	4318800
equipment and machinery	800000	800000	800000	800000	800000	800000	800000	800000	800000	3200000
pipng-material	726725.2	701413	1059187	989928.2	801682.8	1155337	1276928	989262.8	1387636	5695502
pipng-labour	186472	1033662	1033662	243221	1357327	1357327	361505.8	1777446	1777446	1358992
instrumentation (meters)	600000	600000	600000	600000	600000	600000	600000	600000	600000	600000
testing	34350	34350	34350	49125	49125	49125	67500	67500	67500	708000
servitude	91000	91000	91000	131000	131000	131000	180000	180000	180000	265500
sub-total (DFC)	2717927	3539805	3897579	3212824	4138685	4492339	3834934	4963209	5361582	16146794
2 Indirect Field Costs (@ 5 % of DFC)	135896.4	176990.3	194879	160641.2	206934.2	224616.9	191746.7	248160.4	268079.1	807339.7
3 Home Office Costs (HOC)										
project management (@1.5% DFC)	40768.91	53097.08	58463.69	48192.36	62080.27	67385.08	57524.01	74448.13	80423.74	242201.9
engineering draft and design (@3% DFC)	81537.82	106194.2	116927.4	96384.73	124160.5	134770.2	115048	148896.3	160847.5	484403.8
construction management (@2% DFC)	54358.54	70796.1	77951.58	64256.48	82773.69	89846.78	76698.68	99264.18	107231.6	322935.9
home office expenses (@13% of other HOC)	27431.99	34376.85	37400.04	33534.61	41358.14	44346.51	41180.19	50714.11	54080.37	170955.4
surveying	34350	34350	34350	49125	49125	49125	67500	67500	67500	265500
sub-total HOC	238447.3	298814.2	325092.7	291493.2	359497.6	385473.5	357950.9	440822.7	470083.2	1485997
Sub-Total	3092271	4015609	4417551	3664959	4705117	5102429	4384632	5652192	6099745	18440131
4 Other Costs										
VAT (@11% of Sub-Total)	340149.8	441717	485930.6	403145.4	517562.8	561267.2	482309.5	621741.1	670971.9	2028414
Contingency @ 17% of Sub-Total)	525686	682653.6	750983.6	623043	799869.8	867413	745387.4	960872.6	1036957	3134822
sub-total other costs	865835.8	1124371	1236914	1026188	1317433	1428680	1227697	1582614	1707929	5163237
Total Installed Value (TIV)	3958107	5139980	5654465	4691147	6022549	6531110	5612328	7234806	7807673	23603368
cost per erf	3298.422	4283.317	4712.054	3909.289	5018.791	5442.591	4676.94	6029.005	6506.394	19669.47
% of costs going into labour	4.711141	20.11023	18.28046	5.184681	22.53741	20.78249	6.441281	24.56799	22.76537	5.75762

summary table

	35	22	9.2	2
steel	3298.42	3909.29	4676.94	19669
HDPE	4283.32	5018.7	6029	
polyflow	4712.05	5442.5	6506.4	

Appendix D: Maintenance, Service and Operating Costs.

1. Operating and Maintenance costs in Rands per annum (costs per domestic supply point assuming an S1 breakeven 537 kWh/month at 21.75c/kWh)						kWh/month at 21.75c/kWh	
ADMD du/ha	ESKOM	CPA	ESKOM	CPA	CPA	CPA	
	OH	ABC	OH	ABC	UG	UG	
	0.50	1.00	4.00	4.00	1.00	4.00	
	ESK 0.5	CPA 1.0	ESK 4.0	CPA 4.0	CPA UG 1.0	CPA UG 4.0	
108.00	756.85	756.85	756.85	756.85	756.85	756.85	
100.00	756.85	756.85	756.85	756.85	756.85	756.85	
40.00	756.85	756.85	756.85	756.85	756.85	756.85	
36.00	756.85	756.85	756.85	756.85	756.85	756.85	
20 du/ha	756.85	756.85	756.85	756.85	756.85	756.85	

2. Operating and Maintenance costs per annum (costs per metre of road per annum)						kWh/month at 21.75c/kWh	
ADMD du/ha	m/du	ESKOM	CPA	ESKOM	CPA	CPA	CPA
		OH	ABC	OH	ABC	UG	UG
		0.50	1.00	4.00	4.00	1.00	4.00
		ESK 0.5	CPA 1.0	ESK 4.0	CPA 4.0	CPA UG 1.0	CPA UG 4.0
108.00	23	32.91	32.91	32.91	32.91	32.91	32.91
100.00	28	27.03	27.03	27.03	27.03	27.03	27.03
40.00	63	12.01	12.01	12.01	12.01	12.01	12.01
36.00	66	11.47	11.47	11.47	11.47	11.47	11.47
20 du/ha	100	7.57	7.57	7.57	7.57	7.57	7.57

ABC = Aerial Bundle Conductors

CPA = Cape Provincial Council

du = dwelling unit

ha = hectare

Tariffs of city councils and Eskom S	Johannesburg		Pretoria		Cape Town		Durban		Pietermaritzburg		Bloemfontein		East London		Es			
	credit	credit	credit	pre-pay	credit	pre-pay	credit	pre-pay	credit	pre-pay	credit	pre-pay	credit	pre-pay	incl vat	excl vat	incl vat	excl vat
Capital cost recovery	n/a	n/a	n/a	n/a	n/a	6.07	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.68	4.11	4.66	4.09
Average/break-even household consumption	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	350.00	350.00	537.00	537.00
Tariff/unit consumed (excl vat)		13.55	15.593	13.29	n/a	16.805 #	24.82	12.291	12.291	11.75	n/a	19.996	17.375	21.47	18.83	24.80	21.75	
Operating cost recovery	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	11.09	9.73	13.38	11.74	
Capital charge	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.27	0.24	n/a	n/a	
Consumption charge	n/a	n/a	n/a	n/a	n/a	18.75	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Monthly service charge	Rands	0	37.22	0	n/a	0	*	0	0	n/a	n/a	0	0	9.81	8.61	20.00	17.54	

(Sources: Eskom Pricing Policy, National Electrification Forum supplier database, and telephonic communication with electricity distributors.)

vat = 14%

*= included in the consumption charge

#= for the first 300 units, thereafter 15.537c/unit

\$= Eskom calculates their S tariffs based on costs and consumption

n/a= either not available or not included in the tariff build-up

Energy supply report

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