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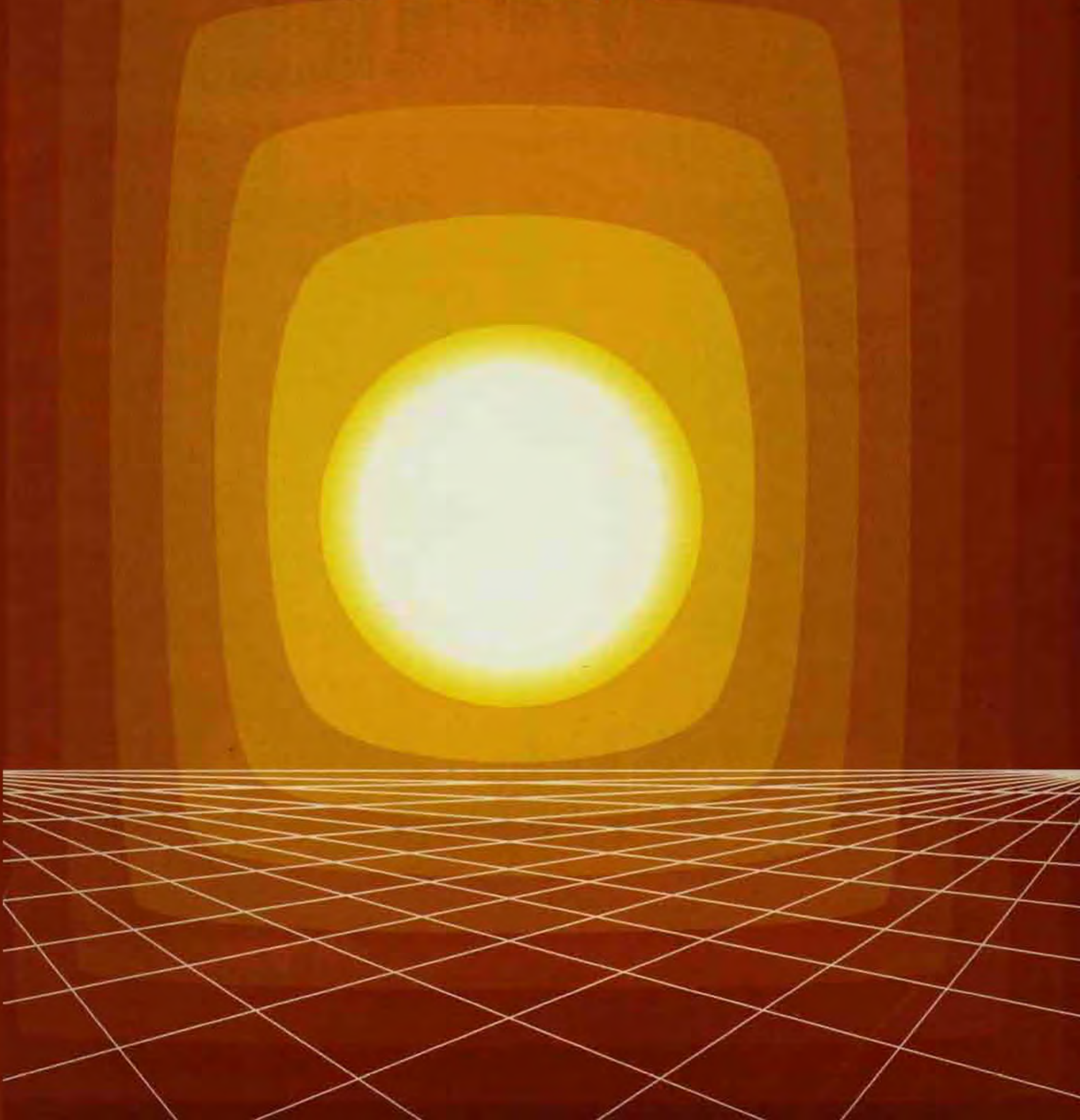

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It is the policy of the Journal to publish, as far as possible, papers covering the technical, economic, political, environmental and social aspects of energy. Only previously unpublished work will be accepted. However, conference papers delivered but not published elsewhere are also welcomed. Short discussions, not exceeding 500 words, on articles published in the Journal are also invited. Items of general interest, news, technical notes, reviews and research results applicable to the Southern African context will also be included. Announcements of relevant publications, reviews, conferences, seminars and meetings will be included.

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Editorial

Y BLOMKAMP

The papers in this issue examine various aspects of the complex subject of traditional/transitional fuel use in the domestic sector in largely, the underdeveloped areas of South Africa. This is the first time that the Journal has devoted an entire issue to a specific area of interest.

The papers look at the use of these fuels from different viewpoints – technical, scientific and socio-economic. The first paper describes a method for and the results of an investigation into the efficiency and cost-effectiveness of space heating appliances as used in rural and peri-urban communities in South Africa.

The following two papers focus in different ways on the impact of socio-economic factors on fuel use in underdeveloped areas. Based on case-studies, one of the papers examine fuel use patterns in a squatter settlement in the Western Cape, showing that transition theories, which are often based on theoretical premises, may not offer explanations of fuel use patterns at the micro-level. Based on her research findings, this author suggests that these theories fail to take into account the complex social interactions which define fuel use and choice in particular contexts.

Using the way in which the women in her research study perceive their housekeeping roles, particularly cooking, as well as the accessibility and relative affordability of paraffin as a fuel, the next author looks at the role of domestic fuel in the lives of the women in an informal settlement near Durban.

Highlighting environmental problems associated with the use of traditional/transitional fuels, the last paper in the issue describes the results of research into the effects of human exposure to air pollutants generated by burning wood and coal for cooking and heating in developing communities in the Transvaal. The research indicated that exposure to the pollutants, emitted from stoves in an unvented or poorly vented environment, greatly exceeded recognised health standards.

This issue then, in focusing on the use of traditional/transitional fuels and their related problems, is a reminder that this is an important matter which needs to be addressed in energy planning for the "new" South Africa.

Profile: J P Brand

Joachim Paules Brand, known as JP to his older associates, or Oom Polla to the younger generation, was born in 1920 in the harsh environment of Gobabis in Namibia. His birthplace, near Leonardville, was far enough away from civilization for the registration of his birth to have to wait for a policeman who came, riding a camel, every three months to the area. Soon after his birth, his parents moved to the Stampriet area and settled on a farm near the Auob river, south of Gochas in the Kalahari.

The remoteness of the region resulted in JP only starting school at the age of 12. His high school years were spent at Swakopmund and Windhoek, and he matriculated from Windhoek High School. After working for a year as an assistant to a drilling contractor in the Kalahari, he obtained a degree in Electrical Engineering in 1944 from the University of Cape Town (U.C.T.). However, money was scarce and in order to see himself through university, JP worked as a steward on the Cape Town-Johannesburg passenger trains during vacations.

In 1945, JP joined the old Electricity Supply Commission (Eskom) and studied for his MSc. degree at U.C.T., which he received in 1947. Thereafter he was awarded a two-year scholarship for post-graduate study in the United Kingdom. He undertook research work at well-known firms such as, Metro-Vickers, Reyrolle, Parsons and the Central Electricity Generating Board (CEGB).

Returning to Eskom, JP moved rapidly through the ranks from Test Engineer to eventually Deputy Manager of Eskom's Western Cape Undertaking.

In 1960 he was asked to carry out a feasibility study of the Ruacana hydro-electric power station, followed by the planning, design and construction of the 220 kV line linking Ruacana to the main electricity grid. In 1972, JP was seconded by Eskom to the newly created South West African Electricity Commission (Swawek). He retired as General Manager in 1982 but was almost immediately reappointed by the Swawek Board as Managing Director, followed in 1988 to date, as Chairman and Managing Director.

His success with the formation and running of Swawek is known to all in the electric utility industry, and the financial soundness of Swawek is proof of his ability. His prowess as a negotiator is legendary, and it is reported that no one has ever got the better of him. In spite this reputation, his colleagues know him as a dedicated and sincere person, always willing to advise and help.

Besides his success in the field of electricity, he also found the time to start a cattlefeed farm in the Western Cape and to establish a mining company, now known as the Trans Hex Group.

JP has also been an active sportsman. He captained the first South African Springbok angling team which competed in 1960 in New Zealand as part of the International Game Fish Contest.

In September 1946, he married Gertruida (Gerty) Catherina van Schalkwyk, a teacher at La Rochelle Girls' High School in Paarl. They have two sons, Johan and Andre.

The efficiency and cost-effectiveness of space heating appliances using traditional and transitional fuels in South Africa

* C B ALLISON

This paper describes the method for and results of an investigation into the efficiency and cost-effectiveness of space heating appliances as used in rural and peri-urban communities in South Africa. A substantial amount of energy is used for subsistence purposes, which places excessive demands on woodlots. Thus improving heating methods would be of benefit to both the heating fuel consumer as well as the environment. It was determined that although cast-iron coal stoves were moderately efficient (37%) as opposed to gas heaters (68%), they are the most cost-effective due to the low price of coal especially in the Transvaal.

Keywords: space heating; traditional fuels; transitional fuels; fuelwood; fuel use; household energy; stoves; energy efficiency; costs

Introduction

The process of social development, especially with urbanisation, is associated with a move from traditional fuels, such as, firewood, dung and agricultural wastes, to the transitional fuels, such as, paraffin, candles and liquefied petroleum gas (LPG). In South Africa, the availability of low-cost coal in certain parts of the country, such as, the Southern Transvaal, makes coal both a commercial and transitional fuel. Eventually the process of social development leads to the use of electricity to the exclusion of most other fuels.

This process is, however, complicated by the relative costs of the various fuels, by people's perception of the heating effect of various fuels, and by the effects of pollution. Thus in Soweto the use of coal is widespread, even where electricity is available, because of the perceived heating effect of coal and its low cost. The situation therefore arises where electricity is used for lighting and television, and coal is used for cooking and heating. Often a single appliance has to perform more than one role, and a coal stove may be used for cooking and space heating. It may not be ideal for either application but is cheaper in terms of capital expenditure. Even in upper-income housing, electricity is not always the preferred fuel for all applications, and oil, coal, or anthracite heaters are often used.

It is thus important to determine the relative efficiencies and costs of the various household appliances in order to determine whether any policy measures can be used to optimise energy use or minimise cost to the end-consumer. Additional concerns are the environmental effects of deforestation and air pollution. There is an increasing shortage of traditional energy, and it is estimated that biomass fuel sources are no longer self-sustaining and that there will be a complete denudation of woodlots within the next two decades[2]. Coal and wood fires are significant contributors to air pollution since the emissions from thousands of small fires are more difficult to control than those from a single power generating plant.

The cost of energy must be integrated with the cost of an appliance, the efficiency with which energy is converted, and the overall life cycle cost. However, it has to be recognised that for many people capital cost is an overriding factor governing energy usage.

This paper covers the factors governing the use of various fuels for space heating in developing communities. The statistics on which appliances are used for this application are very poor and reliance has had to be placed mainly on what is available and selling in the market-place. Consideration has also been given to the non-commercial appliances, such as, open fires, braziers, etc.

Energy usage

Research into the use of energy in developing areas of the country is relatively recent, with early work being carried out by Best[1] in the Transkei and KwaZulu in the late 1970s. Various studies were carried out in the following years and the results have been summarised by Eberhard[2]. He found that the fuels used for different household applications varied with location and with the availability of the various energy forms. Thus in areas with adequate fuelwood, wood is considered a free commodity and is the fuel choice. In areas with no available fuelwood transitional fuels have to be used in spite of their high cost. Thus in Lujiko 92% of households use fuelwood for cooking, whilst only 8% of households in Cottondale use fuelwood. Coal appeared to be a common fuel in most areas.

It has been shown by Viljoen[3] that energy accounts for approximately 12% of the expenditure of rural communities, whilst for urban communities it is approximately 10%. With a move from traditional to transitional fuels the energy cost as a percentage of expenditure decreases. The progression from traditional to commercial energy is via the transitional fuels, such as, paraffin, to coal and eventually to electricity.

Uken[4] showed that the PWV area was largely coal/wood-intensive, whilst areas such as Port Elizabeth, Cape Town, East London and Durban were largely paraffin-intensive for cooking, water and space heating. He analysed space heating fuels used in newly urbanised communities and found that, for the country as a whole, winter heating is mainly by paraffin, which represents 36% of the sample. Electricity is next with 33%, coal has a 25% share, followed by wood with 23%. It is therefore important that the space heating efficiency of typical stoves using these fuels be determined.

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Heater efficiencies

The heater efficiency is defined as the ratio of the energy input into the space being heated to the energy put into the heater. Under equilibrium conditions the energy input is the product of the fuel flow rate and its calorific value. Useful energy from the system is defined as the energy from the stove transferred to the surroundings. This would therefore include the energy put into the air flowing through the heated space, together with any losses through the walls of the enclosure. Details of the determination of heater efficiency are given in Appendix 1.

Various estimates have been made of the efficiency of different types of heaters. Bennett[5] and Viljoen[3] have summarised the estimates of stove efficiency as shown in Table 1.

	Viljoen	Bennett
Electric	80	99
Coal	20	10
Paraffin	50	63
Gas	–	63
Wood	10	–

Table 1: Estimates of the efficiency of space-heaters

Electricity used in a resistance heater has an efficiency of 100% since the power factor is unity and there are no other parasitic losses. The values of efficiency for coal depend on whether an open fire or a closed stove is considered. In an open fire it is not possible to obtain the correct air-fuel ratio and the combustion efficiency tends to be low. The closed stove is more amenable to the control of the air-fuel ratio.

Space heating

Space heating is usually affected by electricity, coal, paraffin, and wood. In many cases the processes of cooking and heating are linked, where the stove is left on to provide heat. Such a combined cooking and heating arrangement is not optimal from the point of energy efficiency, but it is often the best capital cost-effective method. In general, people are unaware of energy efficiency and thus appliances are not usually selected to optimise energy usage nor to minimise cost. The open wood fire is very energy inefficient for cooking purposes. A rudimentary guard around the fire would improve energy usage but this is seldom applied.

Space heating is affected by a number of heat transfer processes. Thus the open coal stove is predominantly a radiative appliance with a significant heat loss up the chimney by convection. A closed coal space-heater is predominantly a convective device. Conduction plays an insignificant role in the heating process as most heaters are combination radiative and convection devices. In the enclosed space of a house, the heating process occurs through a system of radiation and convection to the air in the space and to the walls of the space. In turn, the walls transfer heat to the space by radiation and convection although, since the wall temperatures are low, the radiation contribution from the walls is low.

Heat loss from the space occurs by conduction through the walls and ceiling, and by heated air being lost from the space. The amount of heated air lost is a function of the tightness of the space enclosure, with air ingress and loss taking place through open doors, around the edge of closed doors, around window panes, through air-bricks, and through openings in the ceiling or roof. Rooms with no ceiling but only a roof, are more likely to loose heated air than rooms with ceilings.

If it is required to determine the overall efficiency of the heating appliance, a measure of the heat output in terms of the heating of the surrounding space, the heat loss by conduction from the walls of the space, and the heat input in terms of the fuel consumed, are the only parameters which need to be measured or calculated.

Thus the energy input into the system is given by the mass flow rate of the fuel and its calorific value. The energy output is the summation of the energy input into the air which leaves the space and the heat loss through the walls of the space. If these two quantities are known, the efficiency of the space-heater can be determined. The determination of the efficiency of the appliance can therefore be expressed in the form:

$$\text{Efficiency} = \{m\, c_p\, (T_a - T_o) + U\, (T_{wi} - T_{wo})\} / M^*CV$$

where m is the mass of air lost from the space in unit time, and T_a and T_o are the inside and outside air temperatures respectively. U is the conductance through the walls, M is the fuel mass flow rate, and CV is the fuel calorific value. T_{wi} and T_{wo} are the surface temperatures of the wall inside and outside respectively, and account for the heat conduction through the walls.

In a house, the value of m is difficult to determine under real conditions since it is affected by the movement of people through the space, the number of times doors are opened, and even by the changes in the direction of the wind outdoors, which changes the pressure difference between the outside and the inside of the dwelling.

Whilst it is possible to measure the various parameters in the field, the determination would be so dependent on day-to-day variations, including the outside temperature, that comparative field measurements of the efficiency of various space heating appliances are not possible. It is therefore considered that a test procedure, which would be the same for various heating appliances, would be preferable.

Test methodology

It was decided that the optimal testing procedure should involve a test set-up that would simulate the heat transfer process in a dwelling. Ideally the test should be carried out in a space which is the same size and shape as the actual dwelling-space. It is not necessary, however, to simulate the full size as long as the space is sufficient to be representative of the heating process in terms of convection cell size. A small enclosure would allow for more accurate control of temperature than a very large enclosure and would have less thermal lag than a full-scale enclosure.

The test procedure selected involved the operation of a space-heater in a small test cell which was adequately insulated and which had a low thermal inertia, allowing conditions to stabilise quickly. The appliance was fuelled in the normal manner whilst inside the test cell. Air was allowed to enter through the front of the cell and was abstracted from the back through a flow-measuring device by a blower. The difference in temperature between the air entering the cell and that abstracted, was kept constant at 15°C by varying the flow through the blower. Since varying the flow rate would vary the internal pressure inside the cell, affecting combustion efficiency, the internal pressure was kept constant at just below atmospheric by throttling the inlet air.

Test cell

The test cell measured 1,8 metres square by 1,2 metres high and was constructed from a double layer of asbestos sheeting, supported by a wooden frame. Expanded polystyrene foam insulation was inserted between the asbestos sheets. One of the walls was hinged so that it could be opened like a large door, to allow the installation and removal of each heater. This door was kept closed during operation but had a small perspex viewing port and a perspex fire-box sliding access panel for stoking, refuelling, ash removal, and it doubled as the air inlet. A tilted manometer was used to monitor the internal pressure which was kept close to atmospheric during operation by adjusting the sliding access panel.

A ceiling-mounted fan was used to stir the air and promote even temperature distribution. The bleed air was drawn off by a centrifugal fan discharging through an orifice plate and a throttle valve. Six thermocouples were located and numbered for temperature measurement and orifice flow measurement correction. Where necessary the thermocouples were shrouded to prevent radiation influencing the readings. (See also Appendix 1 at the end of the paper for more details on the test cell.)

Types and selection of space-heaters

The manufacturers of coal stoves can be grouped into two classes:

(1) The first comprises those which utilise capital-intensive facilities to perform casting, steel-pressing and baked enamelling. High turnover and sophisticated machinery help to produce a high quality product at a reasonable price. This group consists mainly of Falkirk Industries and Univa. They are well-established manufacturers serving the urban and fringe urban population[6].

(2) The other class of manufacturer comprises much smaller concerns, performing mainly cutting, bending and welding of mild steel plate and sheet. These manufacturers have all relatively recently established themselves as a result of a perceived gap at the lower end of the stove market. By introducing cheaper versions of established designs they have attempted to attract the rural market.

Most of these stoves are primarily cooking devices, although there is sufficient heat loss from the surface for them to act as space-heaters as well. It is considered that most of the space heating using coal is by means of such "dual-purpose" devices, though there are available space-heaters as well. Both anthracite and coal stoves are available and it was decided to test both types. Two anthracite stoves were tested, namely, the Queen and Coronet, and a coal stove, all three supplied by Falkirk.

The main type of paraffin heater is the wick-type. Primus-type heaters are available but they do not appear to be popular with the general public. The heater tested was made by Sikeni from sheet steel, and incorporated a multi-wick burner. It also has a grate which can be used for supporting a single pot.

The gas heater normally used in newly urbanised and squatter housing is the Cadac-type, which uses bottled gas. There is little, if any, use of town gas. The gas heater tested was a Cadac screw-in, infra-red heating element.

Wood is used either in an open grate or in a wood stove. Unlike other countries in Southern Africa, there is no commercial wood stove available on the market. Most of the wood-burning is carried out in the traditional manner under a pot. A wood fire was tested in a grate with a brick hearth forming a fireplace.

A brazier or paola is a traditional Lesotho stove which was made from an old can or drum by punching holes randomly in the sides and bottom. Some chicken-wire was bundled up and placed in the bottom to form a grate for the coals to rest on.

Results

The measured efficiencies[8] of the various stoves are shown in Figure 1, along with the estimated efficiency of an electric heater taken as unity, which is included for comparative purposes.

The costs of the various fuels have been obtained based on the retail prices of transitional fuels in small quantities. Thus paraffin is sold on a "per bottle" basis. These prices are given in Table 2 for Johannesburg and Cape Town.

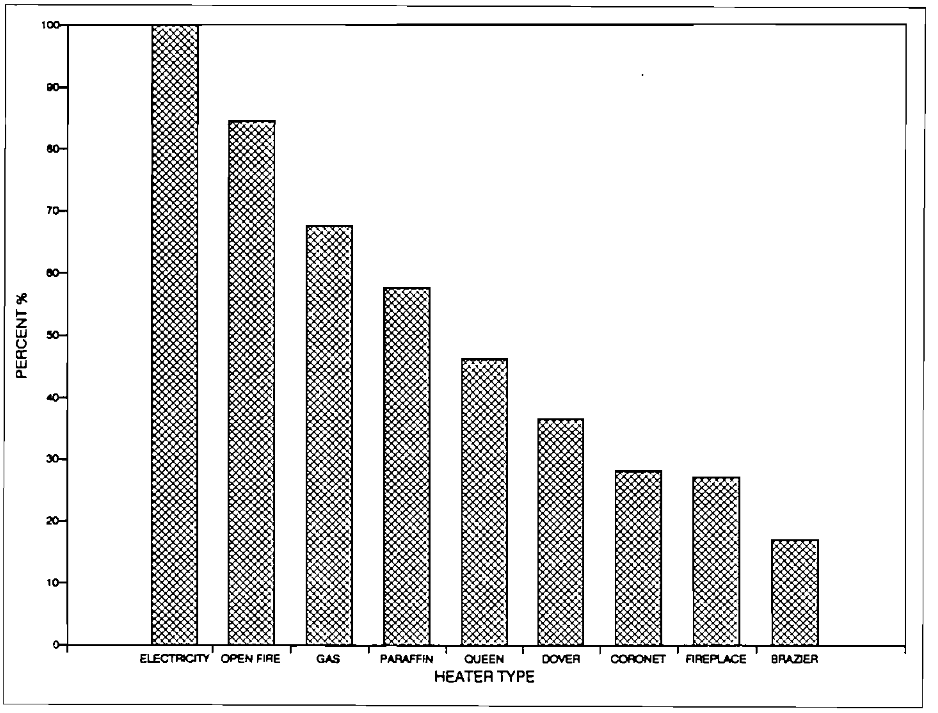

Figure 1: *Relative heater efficiencies*

FUEL TYPE	CV MJ/Kg	JOHANNESBURG R/Kg	JOHANNESBURG c/MJ	CAPE TOWN R/Kg	CAPE TOWN c/MJ
coal	23,60	0,20	0,85	0,31	1,32
anthr.	31,70	0,48	1,52	0,74	2,34
paraffin	46,70	1,66	3,55	1,57	3,38
LPG	49,10	3,12	6,36	2,79	5,68
wood	18,10	0,50	2,76	0,50	2,76

Table 2: *Fuel prices as bought in small quantities*

APPLIANCE	COST (Rands)	LIFE (Years)	EFFICIENCY (%)
Dover 88	960	15	36,80
Coronet	500	15	28,20
Queen	310	15	46.20
Brazier	0	2	17,10
Paraffin	50	5	57,70
Gas	120	5	67,70
Fireplace	120	15	27,20
Electric	53	5	100,00

Table 3: Heater costs and efficiencies

Table 3 lists approximate prices of each appliance for the Transvaal and Cape Province, along with estimated life efficiencies.

The cost of operating a stove is made up of its capital cost and the fuel supply cost. The capital cost of the stove is spread out over its lifetime and is a function of the number of operating hours in the year. Increasing the number of operating hours has the effect of spreading the capital cost of the appliance over a longer period, thereby reducing the operating cost. The operating cost of heater types, such as a wood fire or brazier, which have no capital cost, is constant regardless of operating hours in the year. The running cost depends on the fuel type and stove efficiency as can be seen in the formula below.

Operating cost = capital cost + running cost

$$= \frac{\text{heater cost x 3,6}}{\text{life x hours x output}} + \frac{\text{energy cost (c/kWh)}}{\text{efficiency}}$$

where "output" refers to the heater's operating output in kilowatts and "energy cost" is the cost per kWh of the fuel.

The running costs of each appliance are tabulated in Tables 4 and 5, depending on whether the appliance is being operated in the Cape Province or Transvaal. The output in the above equation has been based on the rated or estimated output for each device.

The total operating costs were calculated for each appliance, assuming 1 000 hours operation per year. These results are displayed in Figures 2 and 3 which indicate that the capital costs are a small proportion of the total costs. It was found that operation for periods other than 1 000 hours did not significantly affect the results.

Discussion and conclusions

The space heating efficiencies of the cast-iron stoves are moderate, ranging between 28% and 46%, but the operating costs of these stoves are the lowest even when compared to electric heaters. This is because anthracite and especially coal are relatively cheap, particularly in the Transvaal. The Queen is the more efficient of the two anthracite stoves due to the fact that it is designed as a space-heater with a large radiant surface, unlike the Coronet which is designed for cooking applications. The Dover 88, which is a coal stove, is sold in far greater quantities then the Queen, indicating that stoves are bought mainly for cooking and that the space heating application is secondary. The good combustion chamber design of the Dover ensures a relatively high heating efficiency and makes it virtually smokeless. Normally, bituminous coal emits black smoke when burnt, whilst anthracite, having fewer volatiles, is smokeless.

The brazier burning anthracite has high running costs, especially in the Cape Province, since the efficiency is poor at 17%. The operating costs would improve if coal or wood were used. There is no means of controlling the air-fuel ratio in the brazier to provide adequate combustion efficiency, therefore the space heating efficiency is low. As with open fires, these appliances should not be operated in an unventilated enclosure.

The wood fireplace with grate has a low initial cost but, since it has a low efficiency of about 27%, it has a fairly high operating cost. The low efficiency is due to poor air access conditions and the non-uniform air-fuel ratio across the bed.

Gas and paraffin heaters have similar efficiencies of about 60%, better than that of any other practical heating device, but because gas and paraffin are relatively expensive and their capital costs are relatively high, their operating costs are high. There is no flue to exhaust into the atmosphere, hence losses are minimal. It must be remembered, however, that all the water vapour formed during combustion is exhausted into the living area. Similarly, unburnt hydrocarbons are also introduced into the space by the paraffin heater. Paraffin is a relatively clean fuel, but problems would occur if other fuels, such as petrol, were to be used in place of

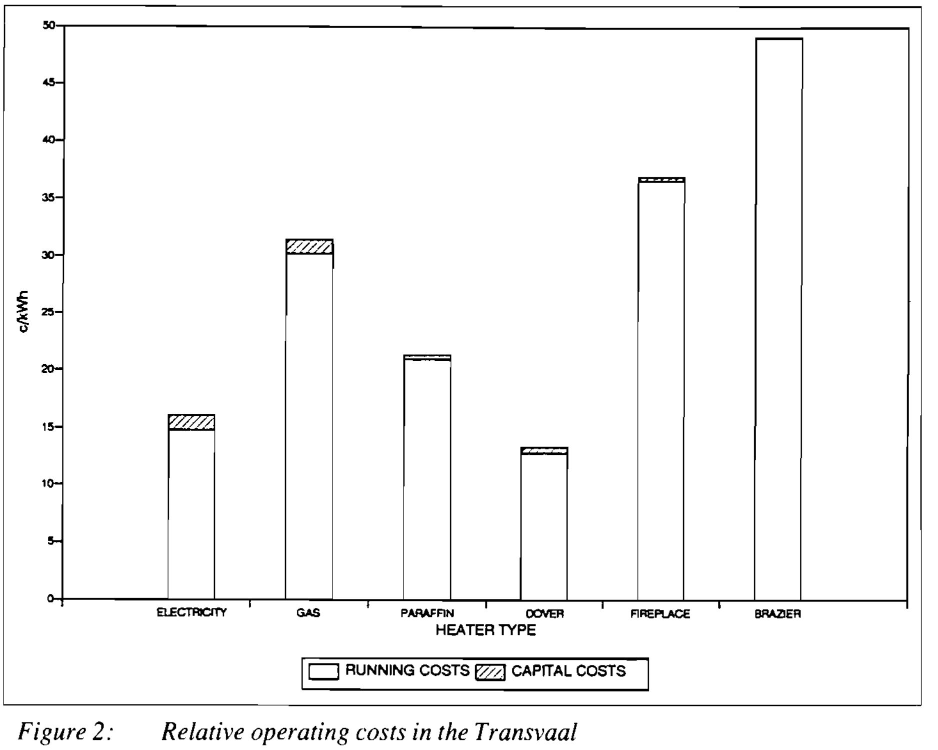

Figure 2: Relative operating costs in the Transvaal

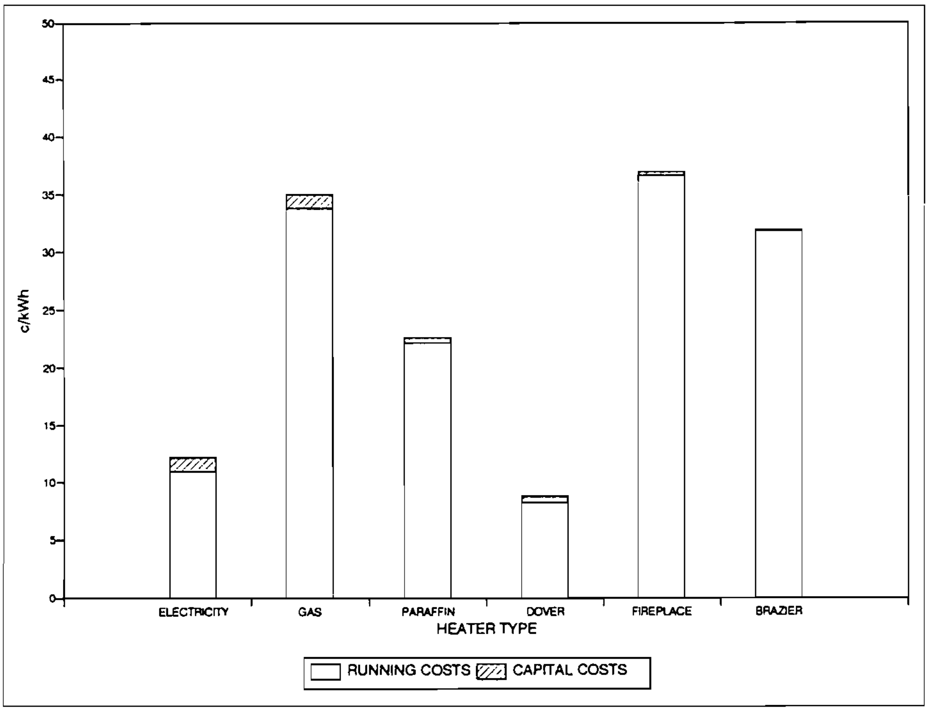

Figure 3: Relative operating costs in the Cape Province

FUEL (Units)	PRICE (R/kg)	CV (MJ/kg)	EFFICIENCY (%)	COST (c/kWh)
Coal	0,20	23,60	36,80	8,29
Gas	3,12	49,10	67,70	33,79
Paraffin	1,66	46,70	57,70	22,18
Anthracite	0,48	31,70	17,10	31,88
Wood	0,50	18,10	27,20	36,56
Electricity	–	–	100,00	10,92

Table 4: Heater running costs in the Transvaal

paraffin. Such use of petrol could occur if petrol was sold at a price lower than that of paraffin.

These costs do not take into account the social, medical and environmental costs which, in the case of fires and braziers, could be significant.

Appendix 1: Determination of the efficiency of a stove as a space-heater

Consider the system as shown in Figure 4. It is assumed that the system has reached an equilibrium temperature after the initial firing-up. The air entering the enclosure is used in two ways: firstly, some of the air is used in the combustion process and is not available to heat up the enclosure (m_2 = where m represents the mass flow rate). Secondly, the remainder of the air (m_1) is heated by convection and radiation from the stove and is considered as the sink for the useful energy. Besides the convection and radiation from the stove to the air, there is also radiation from the stove to the walls, convection from the walls to the enclosure air, and energy loss through the walls of the enclosure. The loss through the walls of the enclosure is a function of the construction of the walls (and the roof) and cannot therefore be debited to the losses from the stove. Thus the wall losses are added to the useful energy in the enclosure air to determine the efficiency of the stove.

In the diagram, the incoming air has been drawn as though there were two separate inlets in order to differentiate between the two air uses described above.

FUEL (Units)	PRICE (R/kg)	CV (MJ/kg)	EFFICIENCY (%)	COST (c/kWh)
Coal	0,31	23,60	36,80	12,85
Gas	2,79	49,10	67,70	30,22
Paraffin	1,57	46,70	57,70	20,98
Anthracite	0,74	31,70	17,10	49,14
Wood	0,50	18,10	27,20	36,56
Electricity	–	–	100,00	14,84

Table 5: Heater running costs in the Cape Province

The useful energy for space heating is therefore given by the equation:

Useful energy = (m_1 * (T_{out}-T_{in})) + heat loss through the wall, where T_{out} and T_{in} are the air outlet and inlet temperatures respectively.

The energy input is given by Q_{fuel} where

Q_{fuel} = mass flow of fuel * calorific value of fuel.

With an electric heater there is no combustion air and therefore all the inlet air becomes the outlet air. If it is assumed that the electric heater is a purely resistive load then the energy efficiency of the heater itself is 100%.

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References

(1) BEST M (1979). The scarcity of domestic energy: A study in three villages. SALDRU, University of Cape Town. Working Paper No. 27

(2) EBERHARD A A (1986). Energy consumption patterns in underdeveloped areas in South Africa. Energy Research Institute. Report No. INT 094.

(3) VILJOEN R P (1990). Energy use in low-income dwellings in the winter rainfall area. Energy Research Institute. Report No. GEN 138.

(4) UKEN E A and SINCLAIR D (1991). The effective use of energy in newly-urbanised homes. NEC Project 14/6/5.

(5) BENNETT K F (1977). Energy utilisation in South Africa. Energy Research Institute.

(6) DICKSON B and BALDWIN S (1990). The development of low-cost fuel-efficient wood-burning stoves appropriate for underdeveloped areas of South Africa. Energy Research Institute. Report No. GEN 136.

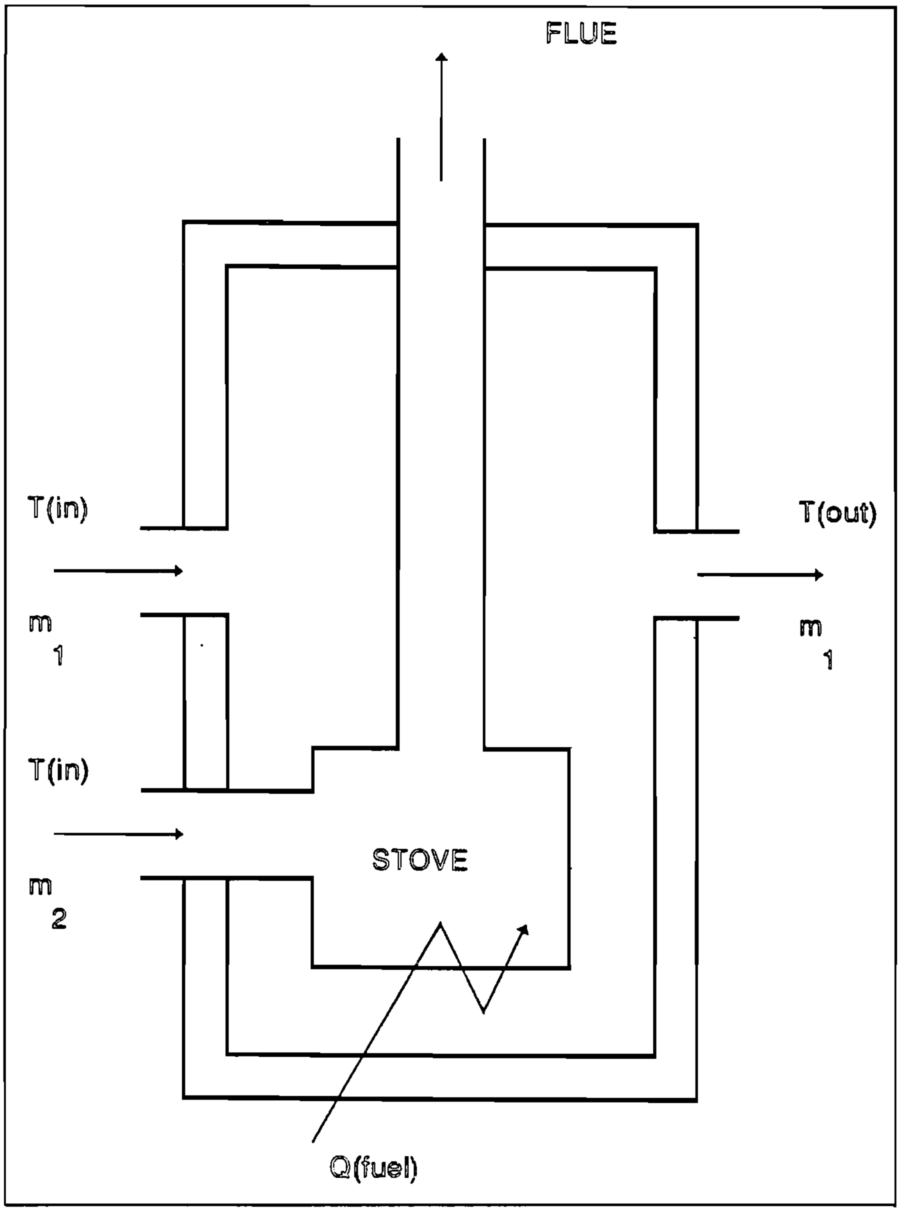

Figure 4: Insulated test cell

(7) HOLMAN J (1986). Heat transfer. 6th ed. McGraw-Hill, London.

(8) ALLISON C B and DUTKIEWICZ R K (1992). The efficiency and cost-effectiveness of space heating appliances using traditional and transitional fuels in South Africa. Engineering Research (Pty) Ltd. Report No. IER 073.

Transforming transition: Exploring transition theories in the light of fuel use in a squatter settlement

* F ROSS

This paper explores some of the international and national literature relating to the fuel transition process and compares it with data obtained from research in an informal settlement in the Western Cape. The comparison indicates that the transition models have little explanatory value at the micro-level. Research undertaken in this settlement points to an extremely complex process of fuel use and decision-making in which criteria other than household income and fuel efficiency are taken into account. The relationships which are constructed through and around fuel are profoundly social and extremely fluid, making prediction of fuel use trends in the contexts of this and other similar informal settlements problematic.

Keywords: transitional fuels; Western Cape; squatters; fuel use; household energy

Introduction

This paper provides a critique of transition models of urban development and fuel use in terms of their theoretical approach and predictive value when applied to informal settlements. It is argued that the transition models are based on theoretical premises which do not take account of power relationships, assuming homogeneity in access to resources - a homogeneity which certainly does not exist in South Africa, where

> ...[d]evelopment has seldom been even or equitable ... In South Africa these inequalities are particularly evident not only in terms of personal income but also in terms of access to basic services and needs such as food, shelter, health, education, sanitation, water and energy supplies. Energy usage provides one striking example of processes and conditions of development and underdevelopment in South Africa.[1]

The second part of the paper discusses research conducted in an informal settlement. This research illustrates that transition theories fail to take into account the complex social interactions which define fuel use and choice in particular contexts. As a result the predictive value of the theories is limited at the micro-level.

Transition models: A theoretical critique

Theories informing patterns of fuel use are somewhat contradictory, at least in their application to South Africa. The most prevalent of the theories is one which posits some process of "modernisation" corresponding to "urbanisation". It is argued that

> The domestic energy transition process seen as a whole is one of the complete substitution of biomass fuels and the progressive adoption and abandonment of transitional fuels before the final stage of complete dependency on electricity is reached... **It can ... be adequately described in terms of "modernisation", which can in turn be determined by education levels, time urbanised and a number of other variables...**[2]** (Author's emphasis).

Such theories do not adequately take into account unequal power relations between what dependency theory calls "metropoles" and "satellite" areas. "Modernisation theory", derived from neoclassical economics, is widely used to justify electrification, urbanisation, economic growth***, and even fertility control[4]. Users of such theories tend not to unpack them (although Foley[5] begins to examine the mythical relationships between fuel use and development), thus making the understanding of fuel choices problematic[6]. For example, it is quite often implied that reasons for incomplete conversion to electricity in areas where it is available is a product of some "traditional" mode of thought - requiring a social explanation, rather than a political-economic one.

"Transition" models are particularly problematic in the social sciences as they imply linear development and an assumption that people and societies move in a straight line from "undeveloped" or "traditional" to "developed/modern". Crudely put, the energy transition model argues that households move along a scale of modernisation, from reliance upon biomass fuels, to use of gas, and then to reliance upon electricity. Corresponding to this is the assumption that such linear progress is accompanied by an increase in "development" or "modernisation".

It is problematic in the South African setting to try to examine the relationships generated by fuel use in terms of such theories. It is likely that individual household fuel use is governed by a host of other factors over which its members may exercise no control. Such factors include difficulties in gaining access to housing (in the Western Cape alone there are more than 65 000 shacks[7]), regular income, and security of tenure. People who have been resident in urban areas for many years and may even have been born in such areas may not have access to housing or "modern" fuels - not by virtue of their own backwardness but as a direct result of the policies of *apartheid*, the legacy which has determined where they live and what jobs they hold. The fact that they do not have access to "modern" fuels thus does not mark them as being members of a "transitional" social organistation, but rather points to the importance of such factors as politics in determining who has rights to become "modern".

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** There is a tension between the theories which inform the models used to illustrate fuel use and the realities of fuel usage on the ground. Viljoen[3] states that, "... use is made of several fuels simultaneously" (p. v), but his 1991 report sticks more closely to a transition-type model.

*** However, note that in his 1990 paper (op. cit.), Viljoen[2] does examine the validity of the concept. Nevertheless, there still appears to be a problematic correlation between modernisation and electrification.

Models such as the transition model, then, tend to focus on macro-level statistical evidence of a movement toward greater reliance on supposed "modern" fuels to illustrate their argument while not recognising that access to these fuels is regulated, to a large extent, by other factors which are in themselves political and social. Moreover, such models are not useful at the micro-level because they do not show the ways in which people make use of different fuels for different purposes, or how people's fuel choices are made in and changed by particular social contexts.

Transition theories: A practical critique

While it is not suggested that such models are useless (which, given the prevalence of their use in international literature, they are not), it is argued that all is not as simple as the theories suggest. Research from Kenya and Grenada[8] indicates that

> ...in both countries the use of more than one fuel for cooking is the norm. Furthermore, households switch between the fuels as part of a conscious strategy based on a trade-off between convenience and cost. This suggests that the process of transition is far more complex than earlier may have been believed since it is apparent that households do not simply switch successively from one fuel to another.

This argument can be persuasively applied to patterns emerging from research undertaken in an informal settlement known as Die Bos in the Western Cape. A seven-month period of participant-observation resulted in a wealth of data relating to changing fuel use patterns, some of it derived from two social surveys conducted in the settlement (one in summer and the other in winter), and much of it the product of a close examination of individual fuel choices and their changing contexts. The resulting data can be used to challenge overly simplistic economic notions of fuel use and fuel choice by showing that, in an area such as Die Bos, fuel use strategies involve conscious manipulation of social relationships, rather than a simple assessment of which fuels are most effective in terms of a household's economy. The resultant patterns of fuel use in Die Bos were thus much more complex than a transition model would predict, and are also more complicated than the model can explain.

Die Bos (and other informal settlements) manifest an extremely high rate of mobility among residents. Over the seven-month period of research in the small settlement, 66 of approximately 100 houses had undergone resident changes of some sort****. Frequently the changes were the result of domestic violence, which caused women to leave lovers for short or extended periods. In other cases, the changes were brought about by the return of children previously absent. Most such residential mobility was contained within the settlement - people moved from one house to another. In all cases recorded there were fuel ramifications, some of which are explored below.

"... in small-scale context, particularly given the present uncertain living contexts of squatters, fuel choice and distribution are political and social as well as strategic choices. In addition, patterns of fuel use in informal settlements are likely to change rapidly - a direct product of residents' insecurity of tenure."

The mobility of the population was not the only aspect which resulted in fuel changes. Fuel sharing patterns, closely interlinked with movement patterns, also determined the kinds of fuels used over time. The case-studies presented below illustrate ways in which the fuel sharing and movement patterns of some people in the settlement affected the fuel choices that they and others made. It should be noted that the case-studies are representative of the kinds of effects that movement in the settlement had in altering fuel use patterns, although the people and frequency of movement were different in each case. Further details of the effects of such movement and fuel sharing have been explored elsewhere[9].

Case 1. The social contexts of changing fuel use

Jemima arrived in Die Bos in March 1992 from Knysna. She was unemployed and had nowhere to live. Her first place of residence in the settlement was with Baby, for whom she did all the housework (including cooking) in return for her board and lodging.

Early in April, Anna, another resident of Die Bos, rebuilt her shack. Anna had only one leg and found it difficult to manage on her own. Jemima moved to her larger home, and again took over all the housework. Anna was recorded as having used paraffin alone as her cooking and heating fuels in the summer survey. However, when Jemima arrived she offered to collect wood on which to cook as part of her domestic duties. Anna agreed, and Jemima collected wood each day on which to cook their one main meal. The money that Anna saved as a result of not buying paraffin was used for entertainment purposes and to feed Jemima.

In this case, Anna swopped from a relatively efficient fuel to one which was technically less efficient but which suited her domestic economy better. Jemima was unable to make a cash contribution towards the household's running costs, but her labour in collecting wood freed some of Anna's cash to be used for other purposes.

In the second case-study, Anna's house was again examined and the changes in fuel use with the arrival of another lodger, Ou Rose.

Case 2. Further movement and change

Ou Rose was an old crony of Anna's. In May, she moved into Anna's shack after her own had burnt down. Jemima was still resident at Anna's at this stage. Ou Rose contributed R50 per month towards her upkeep, and this was used to buy food and alcohol. Jemima continued to collect wood until the end of May, when she moved into another house in Die Bos. At that point her labour contributions to Anna's domestic unit ceased, and Anna began to cook on her paraffin appliances again, as Ou Rose suffered severe arthritis and could not collect wood.

**** There were 132 sites by the end of the research in June 1992.

This was a source of some conflict between herself and Ou Rose, because the latter refused to bring her gas stove to Anna's, having loaned it to Katherina, another friend (see Case 4). Eventually the conflict became so bad that Ou Rose moved out.

Anna left her home for a few days and went to stay with a friend, taking her paraffin stove with her. Since her friend had been using wood, and Anna had agreed to pay for paraffin, this was a welcome move, relieving the need to collect wood in the rain.

Three weeks later Anna returned to her home, and she and Ou Rose patched up their argument. Ou Rose again became a lodger at Anna's, this time bringing her gas appliances with her.

In the space of three months, Anna's main cooking and heating fuels had changed four times. In the first instance she was reliant on paraffin. This later changed to wood, which Jemima collected. When Jemima left the house, Anna again began using paraffin. (This was because Ou Rose could not collect wood as Jemima had done and refused to offer more than cash to the arrangement. In particular, she did not bring her gas stove to the house.) The result was that much of the money which Anna had previously had spare to spend on alcohol was now spent on fuel. Ou Rose left and later returned, this time bringing the gas stove with her. Thus Anna's fuel use changed again, this time to gas. There was no guarantee, however, that Ou Rose would stay with her in the long term, and as a result Anna viewed her dependence on gas as temporary.

The case-study thus begins to provide data relating to the complexity of fuel use when seen in the context of frequent movement. Anna's household was not the only one affected by the movements of people related to it. Her own move meant that a different domestic unit was able to rely on paraffin for a while rather than on wood. Jemima's moves had similar effects on the domestic units into which she moved, while Ou Rose's movements between Anna's and Baby's houses first provided and later deprived Baby of access to gas appliances.

Changing patterns of fuel use are also a strategic plan by people hoping to gain residential or commensal (i.e. eating together) rights in a household. Thus Jemima offered to collect wood for Anna in return for lodging, while, as will be seen in Case 3, Korporal, Thelma and Ou Rose performed fuel-related chores or offered fuel appliances in exchange for commensal and limited residential rights.

Case 3: Creating commensality

Korporal and his girlfriend, Thelma, lived in a tiny shack. They seldom ate there, however, as Korporal had offered his services as a wood-collector to Baby in return for rights to eat in her home. Prior to this Baby had bought paraffin for her pressure stove, but as the demands on her income increased (at one stage she was supporting 10 people) her fuel costs had to be cut. Korporal's labour enabled her to do this.

"... it is these social relationships which order fuel use rather than the other way around."

Later, however, Ou Rose (see above) moved in with her, having fought with Anna. Ou Rose took her gas stove to Baby's, and Baby's cooking fuel switched from wood to gas.

When Ou Rose moved out, Korporal's labour in collecting wood again became essential. So essential, in fact, that when he and Thelma decided to leave their house for a few weeks, they were able to claim rights of residence in Baby's house as a result of the work that Korporal had been and was performing.

The couple lived in Baby's house for a few weeks and then moved back to their own shack when their daughter came to stay. Meanwhile Baby had agreed to provide food for several other people who paid her R30 per month for this. As a result she was able to switch from total reliance on wood to using wood and paraffin on which to cook.

In the space of five months, Baby's fuel patterns changed from total reliance on paraffin, to wood, and then to a partial reliance on wood and gas. When Ou Rose took her gas canister away, Baby again began to use wood, and was later able to alternate between wood and paraffin as the residents in her domestic unit changed.

A final case-study will illustrate the continuities and changes within one household over the seven-month research period. Here the rapid turnover in residents within one domestic unit is illustrated, and how this affects fuel choice. It also gives an indication of the ways in which the boundaries of domestic units are extremely permeable - a factor which complicates attempts to delineate "households". The relationships in the domestic unit described below were not *atypical* of those existing throughout Die Bos. This case-study is therefore useful in that it provides a summary of some of the interactions which were occuring at all levels and in most domestic units at some stage in the research.

Case 4: Contextualising movement and fuel sharing

Katherina had been resident in Die Bos for approximately eight months by the end of the research. When she arrived in the settlement she stayed with her sister's boyfriend, Andries, cooking and doing housework in exchange for living-space for herself and her two sons. The main fuel used in the house was paraffin. Katherina decided to build her own home, and left Andries' home, taking with her Kelvin, her sister's epileptic son. Accompanied by her two children and Kelvin, she moved into a large single-roomed house.

At the time that this research was undertaken, Katherina was using a paraffin pressure stove with two burners as her main cooking appliance. On this she cooked for herself, the three children and her boyfriend Pan, as well as occasionally for her mother and sister's daughter who came to visit from Macassar.

In about March 1992, Ou Rose (see above) decided that she no longer wished to eat at her own home. She thus approached Katherina who agreed to cook one meal a day for her on condition that Ou Rose allow her to use her gas canister and ring. Ou Rose agreed and, for R50 per month she ate at Katherina's house each evening.

Thus at that time, Katherina's household was reliant on Ou Rose's gas stove as their main cooking appliance. The domestic unit consisted of the five people who slept there regularly, Katherina's mother and her sister's daughter, who stayed intermittantly, Ou Rose who ate there nightly, and Anna who ate there occasionally.

In April, Katherina's boyfriend invited a friend, Oom Kallie, to stay. He too paid

R50 per month. Occasionally Katherina also cooked for Evelyn, another resident of Die Bos, who would come to visit Katherina's mother and Ou Rose.

Some time later, Katherina and her boyfriend had an argument, and he and Oom Kallie moved into a recently-vacated shack opposite Katherina's. Katherina's boyfriend no longer ate at her house, although Oom Kallie continued to do so.

Meanwhile in late April, Anna (see above), who had eaten intermittently at Katherina's in the preceding six weeks, had enlarged her tiny shack and was looking for a companion. Ou Rose decided to live with Anna. She moved into Anna's home and left her gas stove at Katherina's, even though Katherina had begun using the paraffin stove again, as her mother was visiting for a few months and was afraid of using gas to cook on, believing it to be poisonous.

It was at this time that Katherina lost one of her jobs as a char. Her income decreased by R30 per week, making gas too expensive to use regularly (it cost R10 to fill each fortnight). She thus became more reliant on paraffin and on wood, sending her 11-year-old nephew to collect it.

As seen in Case 2, Ou Rose and Anna had an argument early in June, in part centered on the gas canister still at Katherina's. Ou Rose left Anna's and took the gas canister from Katherina leaving the latter to rely on wood and paraffin for cooking purposes. At this point her household consisted of herself and the three children only.

Soon, however, Oom Joey, an elderly resident in the settlement, heard that there was space in Katherina's house. He left his previous lodgings and moved in, paying R50 per month from his pension as rent and for food. Although he did not offer any fuel appliances as Ou Rose had done, the money he contributed meant that Katherina could afford to buy paraffin more frequently. But in mid-June he left without giving notice, which again constrained Katherina's resources which were especially strained as Katherina's mother and her sister's daughter returned to the household in Die Bos from mid-June until the beginning of July. It was winter and bitterly cold and wet. Katherina had a fire burning all day outside, and a *gally blik* (a perforated 20-litre drum filled with embers) inside at night. She began to prepare her food increasingly earlier in the evening so that the outside fire could be used, saving on paraffin expenditure.

MONTH	RESIDENTS	EATERS	FUEL
1991 Nov.	(Katherina and children resident with sister's boyfriend in Die Bos)		**Paraffin**
Dec.		As above	**Paraffin**
1992 Jan	Katherina 2 S, ZS	–	**Paraffin**
Feb.	Katherina, 2S, ZS, H. Also Katherina's M and ZD who visit intermittently.		**Paraffin**
March	Katherina, 2 S, ZS, M, ZD.	Ou Rose *Anna*	**Gas**
April	Katherina, 2 S, ZS, Oom Kallie moves in. H out. M and ZD visit intermittently.	Ou Rose out. *Evelyn*	**Gas** and Paraffin
May	Katherina, 2 S, ZS M and ZD visit intermittently. Oom Joey in. Oom Kallie out.	Ou Rose takes gas (end May) *Evelyn* *Oom Kallie*	**Paraffin** and wood.
June	Katherina, 2S, ZS, M and ZD visit intermittently.	*Evelyn* and D.	Paraffin and **wood**.

Table 1: *Summary of membership (residential and commensal) of, and fuel used by Katherina's household: Nov. 1991 - June 1992*

CODES:
M = mother
S = son
ZD = sister's daughter
ZS = sister's son
H = common-law husband/ boyfriend

(i) Eaters are those people who ate at Katherina's but did not sleep there.
(ii) Residents are those who ate and slept at Katherina's home.
(iii) *Italics* indicate non-residents who eat at Katherina's intermittently.
(iv) **Bold** print indicates the predominant fuel at each stage.

Table 1 shows Katherina's changing household and related fuel use. It differentiates between the residents and commensal members (eating associates) who clustered around her in each month, and illustrates the ways in which these people and their interactions with Katherina influenced her fuel use over the research period. It should be noted that figures of this type tend to oversimplify the complex interactions which took place. Nevertheless the diagram is important in that it depicts the ways in which fuel use changed over time.

As Table 1 illustrates, there were various shifts in fuels used in Katherina's household over the six-month period described. Initially her household was reliant on paraffin. This reliance then switched to gas with the arrival of Ou Rose and her gas canister. Then Ou Rose took the canister away and the household again became reliant on paraffin, which they were able to afford because of the cash contributed by Oom Joey. His departure, however, combined with the loss of one of Katherina's jobs, meant that her household income was substantially reduced, and as a result wood became the primary cooking fuel.

Case 4 illustrates how peoples' fuel-related decisions and actions are deeply imbued with social meanings and are imbedded in social interactions. Katherina's household underwent a series of changes in personnel, income, and as a result of both of these factors combined, in fuel use. Her use of wood in June was not simply because the weather made further heating essential but was a function of the movement of people into and out of her household, her precarious job status, and the social relationships which she created in and through fuel use.

This raises an important methodological point. Had the results of the two surveys been taken on their own, it would have been assumed that Katherina used paraffin (while resident with her sister's boyfriend during the summer survey), and had then turned to wood and paraffin in the winter survey. This would have implied that she had continued to use paraffin consistently throughout the course of the research, supplementing her fuel use with wood in the colder weather. As shown above, this was not the case. Survey methods alone are not sufficiently sensitive to make sense of the extremely complex fuel use patterns which exist over time. Longitudinal and intensive techniques of research, such as those offered by participant-observation methods, are more suitable in such instances as they are extremely sensitive to contexts and change.

What the examples above have illustrated is that at the micro-level one cannot expect a unilinear pattern which moves from reliance on a biomass fuel to a "modern" fuel. Visits to Sir Lowry's Pass Village, near Die Bos, indicated that the relationships described above persist even where people have access to housing which conforms to municipal requirements. As a result it cannot be stated that the fuel sharing practices and movement patterns described for Die Bos are the product of that particular environment alone. Instead it is necessary to examine social relationships engendered around fuel in a variety of settings before it can be claimed that the transition models have predictive value in the larger South African context. What can be seen above is not the substitution of one more efficient fuel for another, but rational, complex decisions made on the basis of short-term expectations and events that are constrained by macro-level circumstances beyond any of these people's power to influence. This results in rapidly changing patterns which do not appear to have much resemblance to the linear patterns of transition proposed by the prevailing theories.

Conclusions

As the case-studies above show, fuel use patterns among residents of Die Bos were extremely complicated. While space does not permit the inclusion of more case-studies, it is important to state that such instances were not uncommon in Die Bos nor probably are they uncommon in other informal settlements. Models such as the transition model, with its emphasis on broad patterns of fuel change, are not able to account for the complexities of fuel use in settlements such as Die Bos, where the tenuousness of everyday life requires some degree of interaction and co-operation. Thus, as has been seen above, in small-scale contexts, particularly given the present uncertain living contexts of squatters, fuel choice and distribution are political and social as well as strategic choices. In addition, patterns of fuel use in informal settlements are likely to change rapidly - a direct product of residents' insecurity of tenure.

Fuel use and the decision-making processes concerned with it cannot be divorced from their reality "on the ground". The ways in which people interact with one another, both inside and outside of their homes, have a vital part to play in the choices that they make concerning fuel. The main thrust of the argument presented here is that it is not sufficient to make projections concerning informal settlements based on the assumptions that people's fuel use is constant and static, nor that the ways in which they change from one fuel to another will be predicted by the transition model.

Transition theories may well be able to tell us something important about fuel use in permanent dwellings, but they are not adequate to explain the patterns that emerge in informal settlements such as Die Bos. It is not sufficient to assume that residents of such settlements are undergoing a process of "modernisation" themselves. The housing backlog in the Western Cape illustrates that no matter what criteria are used to depict "modernisation", there is little chance that the present residents of Die Bos, or indeed those to come in the near future, will have access to conventional housing and modern fuels. It may be that the individuals involved are themselves transient, but the settlements can be expected to endure over time.

Therefore, in order to examine and explain fuel use in such settlements it is necessary to look at the micro-context of the residents' lifestyles, at the conditions of tenure and security which they experience, and most of all, at the ways in which they are able to use and construct social relationships around fuel. It is these relationships which shape fuel use patterns in Die Bos rather than overtly economistic decisions to utilise the most efficient fuel. To make any sense of these patterns it is necessary to recognise that efficiency and effectiveness are fundamentally concerned with human social interaction, and it is these social relationships which order fuel use rather than the other way around. Fuel is used to create links between disparate domestic units, to generate webs of obligation which can be activated in times of need. Above all, it should be realised that the networks of fuel use which are apparent in Die Bos are a social construction, generated and maintained, as well as given meaning by, the particular social, political, economic and environmental contexts in which people find themselves. It is only by realising this that it will be possible to make sense of the complex patterns and webs of obligation which are constructed through fuel use.

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References

(1) EBERHARD A A (1990). Energy consumptiom patterns and supply problems in underdeveloped areas in South Africa. *Development Southern Africa*, Vol. 7 No.3, pp 335-336.

(2) VILJOEN R (1991). The domestic electrification process: A strategic perspective. Paper presented at Eskom seminar, Megawatt Park.

(3) VILJOEN R (1990). Energy use in the low-income dwellings in the winter rainfall areas. Report No. GEN 138, Energy Research Institute, University of Cape Town.

(4) VAN DER BERG S (1990). The socio-economic impact of energy provision to settlements in the rapidly growing metropolitan areas of South Africa, with particular emphasis on electricity. Interim Report No.3, Institute for Futures Research, University of Stellenbosch.

(5) FOLEY G (1990). Electricity for rural people. Panos Institute, London.

(6) EBERHARD A A (1990). Analysis of new urban electrification schemes in the Western Cape. Energy for Development Research Centre, University of Cape Town.

(7) *Weekend Argus* of 4 June 1991

(8) SOUSSAN (1987. Fuel transitions within households. *In:* Transitions between traditional and commercial energy in the Third World, pp.4.1-4.32. Ed. by D Hawdon, P Pearson and P Stevens. Surrey Energy Economics Centre, SEEDS No. 35.

(9) ROSS F (Forthcoming). Final Report for the National Energy Council on research undertaken in Die Bos. Dept. Social Anthropology, University of Cape Town.

Fuel for thought

* W ANNECKE

This paper examines the role of domestic fuel in the lives of particular women who live in an informal settlement in an urban area in South Africa and who do not have access to electricity in their homes. The paper argues that paraffin in particular, is likely to continue to be used extensively in the future, despite its disadvantages and the desirability of electricity. The paper submits that the reasons for this pertain to the manner in which women perceive their housekeeping roles, particularly cooking, as well as the accessibility and relative affordability of paraffin to households whose buying power is constrained as much by the form in which income is derived as by its inadequacy. This argument is elucidated through the case-studies of ten women who live in non-electrified homes.
Furthermore, the paper argues that there is no simple equation between household income and fuel purchase, and that national energy planners should take the above factors into account in order to determine strategies and energy policies which would be "woman-friendly", and support the needs of the extensive number of impoverished people in South Africa.

Keywords: household energy; transitional fuels; women; poverty; energy policy; fuel use

This paper describes the first of a series of studies done with** women who live in the Durban area but who do not have access to electricity. There are some 3 million people in the greater Durban area of whom 1,8 million (i.e. over half the population) live in informal settlements[1]. While each shack settlement has been established within a specific set of circumstances and has its own particular history, almost all have a lack of the following basic services in common: no drinking water, no sanitation, no drainage, no access roads, no electricity.

This paper is concerned with the relatively under-researched area of fuels used by women who live in non-electrified homes in urban areas and who have access to biomass fuels, in particular, wood and the so-called transitional fuels, namely, bottled gas (LPG), paraffin, batteries, paper waste and candles. The hypotheses underpinning the investigation were:

(a) in urban areas, domestic energy (including wood) is an essential commodity and accounts for a large proportion of household expenditure, particularly among the poorer sections of the population;***

"... cost is invariably a factor advanced in arguments as to whether or not large-scale electrification constitutes a viable option for low-income households."

(b) women are largely responsible for managing household budgets and the acquisition of fuel and food, yet little is known about how women make decisions about expenditure or how they order their priorities, particularly when survival is an issue.

Equally little is known about women's perceptions of fuel and its use in appliances. The study confirms these assumptions and elucidates women's perceptions of appliances as they pertain to fuel consumption. The consumption of domestic fuel should be placed within the broader context of national and international exploitation of energy resources, and the interests of producers of electricity and paraffin. These vested interests should be borne in mind throughout, although they are not addressed here.

The context of Canaan

The ten women who participated in this study lived in a recently established, relatively small informal settlement ironically, but not cynically, named Canaan, which was located on the periphery of the city of Durban and, at the time, was home to some 429 households. Canaan was hardly the "land of milk and honey", having in common with other informal settlements no infrastructure - including no electricity supply, although it was surrounded by power lines. Under these circumstances, the residents of Canaan used primarily paraffin, candles and wood as sources of energy for heat and light. The distribution of these fuels was largely through the municipal dump and the "spazas"; two arguably positive and salient features of Canaan which warrant brief description.

Firstly, the municipal dump, located some twenty minutes walk from Canaan, played a central role in the lives of the impoverished residents. Most of the materials from which the shacks were built were collected from the dump. In addition, clothes, tinned and frozen food, fruit, vegetables and cartons were salvaged. The latter were chopped up and used as firewood when there was no money to buy paraffin (this is referred to later). Secondly, operating within Canaan were at least five shack shops or "spazas". Spazas were extensions of the shack-dwelling from which a variety of domestic commodities were sold, usually in small quantities and at prices determined by the owner. Spazas generally keep long hours and serve the daily needs of local households, particularly those for whom transport or buying in relatively large quantities is a problem. Paraffin, candles and batteries were sold by all five spazas in Canaan. It was the apparently arbitrary and unnecessarily large hike in the price of paraffin by one spaza owner in particular that prompted this study.

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** Investigations were done with, rather than on, women as we attempted to engage with feminist and participatory methodology.

*** This proportion is likely to be in the region of 20% of lower income households, whereas it is likely to be only 4-5% of the income of white urban households.

Methodology

One of the women at the women's group weekly meetings (established to articulate the needs of the women of Canaan) complained bitterly about the increase in the price paraffin (complaints about the increased cost of paraffin were linked to the high price of food and a lack of money). After much discussion and in the face of few alternatives, ten of the women agreed to keep daily records of what they spent on water, food and fuel for three weeks in order to try and quantify their poverty. The records would be used to examine household budgets and expenditure in order to assess the survival strategies employed by the women, and to determine how these could best be supported. These records would be brought to weekly meetings which would be attended by all participants and the researcher, and at which questions and matters pertaining to this monitoring would be discussed. Logging schedules in Zulu and English, as well as visual aids, were compiled, and a trial run was undertaken. Data from these daily schedules, supplemented by details supplied by the participants at the women's group meetings, constitute the bulk of this paper, but two other surveys are also referred to, namely, an "attitudes to energy" survey which was completed by 40 randomly selected households at Canaan[2] and an extensive socio-economic survey completed by 359 households[3]. It was believed that personal assessments of poverty and how these impacted on the way women used fuel played as important a role as the statistics did in the research. The former are elucidated in this paper since the survival strategies employed highlight some of the complexities of budgeting and the importance of the perceived role of the mother in decision-making.

Fuel used for domestic purposes at Canaan was monitored and discussed in terms of appliances owned and used, different sources of energy used, the advantages and disadvantages of wood and paraffin, and costs. The limitations of paraffin appliances were also discussed.

Socio-economic profile of the participants

The ten women participants ranged in age from twenty to forty-eight, with household sizes which varied from two (both adults) to twelve (six adults and six children). The average age of the women participating was thirty-four and the average household size was 4,6 persons. Weekly household incomes overall ranged from R45 to R150 with an average weekly income of R105 per household. This would indicate that the participants were among the 50% of households at Canaan who had weekly incomes of less than R120[3]. Eight out of the ten women were primary or sole breadwinners, while in only two of the households were there wage-earning men. The ten women contributed to the household incomes in a variety of ways: by building shacks, running a shebeen, selling fruit and vegetables at the roadside, hairdressing, sewing, carrying water, doing odd domestic jobs, and selling cardboard collected at the dump.

"Electrification schemes may not be viable unless both the energy and the appliances are subsidised, and unless methods can be designed whereby users ... are enabled to make payments in small, regular amounts as currently happens with the purchasing of wood

The critical factor in this type of income is that both the frequency and the amount are unpredictable. Although a vegetable seller may be able to estimate that she will earn say R20 in a week, she will be dependent on her skill and good fortune at the dump as well as the weather for profitable selling days. This vindicates a "live for today" philosophy and considerably complicates any desire to plan for the longer term.

Appliances and energy usage patterns

A paraffin stove, a paraffin iron and a battery-operated radio were common to all ten participating households. In addition, there was one paraffin heater, one battery-operated torch, one gas stove and one battery-operated television set. None of the participants owned a paraffin lantern nor a gas light.

In terms of sources of energy, the ten households used predominantly candles for lighting, and wood and paraffin for heating and cooking. This was typical of most of the residents of Canaan[3]. With regard to lighting, the ten women tried to limit their households to one candle per evening and for this reason, and because it was easier to find 50c per day than R2,39 for a packet of 6 candles each week, candles were usually bought singly from the spaza shops. When it was pointed out that by doing this the women were paying 20% more for their candles per week, the two households in which there were weekly-waged men bought packets of candles when they next received a lump sum of money. However, as one woman explained, she still had to limit the number of candles used:

> I tried by all means to buy a packet of six and not let my husband know, otherwise he will sit up the whole night using all the candles.

This perception raises interesting questions around household management and authority which are addressed elsewhere[2]. In this paper the inadequacy of one candle is an important issue. In one home the poor lighting was effectively boosted by waxing the newsprint wallpaper. The polished surface reflected the light and enhanced the visibility, allowing the mother and daughter to read at night.

Wood was used by all ten participants as a supplement for paraffin for heating. Although paraffin and wood were both disliked, wood had the advantage of being free or cheap. It was collected from the dump or from the bush some 40 minutes walk from Canaan, or purchased for R2/bundle, weighing approximately 10 kg, which was "brought in from the rural areas" by women simply known as "sellers". As a supplement for paraffin this wood was consumed over 7-14 days. The women described the disadvantages of wood thus: it is not always available to urban dwellers; it is hard work to collect; it is a dirty and smoky fuel while cooking; it is slow; it takes a great deal of time to make and tend a fire, and it has to be made outside. In essence, using wood constitutes physically hard work and is time-consuming.

An important point to note about the settlement at Canaan was that despite the residents' need and the abundance of wood on the site, the women walked considerable distances to obtain wood. The reason for this was that Canaan was established on a steep and geologically unstable site where trees had been planted to hold the soil. When the settlers began to arrive these trees provided an immediate and obvious source of building materials and firewood, but once it had been explained at a community meeting that the trees could not be chopped or removed without the risk of precipitating a landslide, they were not damaged further.

All ten participants used paraffin for cooking and heating. When asked why they used paraffin, the women responded: "It's the only means". Later, when asked why they used wood, the same women replied: "It's the alternative and it's cheaper". On probing these apparently contradictory statements, it became evident that the women referred to paraffin as "the only means" in the absence of something better and because they had so little money. Paraffin and wood tended to be lumped together and compared with something better - gas or electricity. Despite this perception the women, albeit driven by economics, did make choices, and when possible chose paraffin because of its advantages over the lower order fuel, wood. Wood was perceived not as a choice but as a disciplinary measure to save money.

Thoko, who is 39-years-old, told the story of her marriage which included a description of the lobola (brideprice) paid by her husband-to-be to her parents, and interestingly, her perception of his considerateness in giving her paraffin among his gifts:

> He paid all the things that were asked for by my parents ... sleeping rugs, a big, big Zulu three-legged cooking pot ... and 20 litres of paraffin (those days it was a treat to have that much of paraffin), and a primus stove ... This was to say, "I'm grateful, here is paraffin in the stove, you mustn't carry on going to the bush to cut wood"..[4].

However, having come to the city with her husband and worked for years in a wealthy white household where there were appliances, such as, a washing-machine and microwave oven, Thoko's perception of the luxury of paraffin dimmed along with the other women's. In response to the question, "What do you like about paraffin?", 36 out of 40 respondents replied "nothing", 4 shrugged their shoulders and said "no comment"[2]. The ten women who were monitoring their consumption and expenditure on paraffin readily enumerated their complaints about paraffin which fell into the following objective and subjective categories: it is poisonous, dirty, dangerous and expensive. For the purposes of this paper only the last is explored.

The women's complaint that paraffin was expensive was a subjective judgment, predicated on the low incomes received. It is worth spending some time exploring the substance of this allegation, since cost is invariably a factor advanced in arguments as to whether or not large-scale electrification constitutes a viable option for low-income households. In South Africa, paraffin is listed as a strategic fuel, so that statistics of the amount imported or the foreign exchange involved are difficult to obtain. The wholesale price of paraffin is subjected to price control, however, the complex retail structures result in the cost to consumers varying considerably. For instance, on 31 March 1991 when the official price recorded by the National Energy Council was 92,33 cents/litre (c/l)[5], a large supermarket chain store in Durban was selling paraffin for 101 c/l****, residents of Khayelitsha in Cape Town were paying 80 c/l[6], and residents of Canaan were paying between 120 c/l and 150 c/l, depending on the whim of the spaza owner.

> "In this transitional phase, women's use of lower order fuels is determined largely by the harsh realities of poverty."

The issue is not easily resolved. Paraffin is sold relatively cheaply in bulk at some petrol stations and supermarkets. To buy in bulk the residents of Canaan would have needed at least R20, the bus- or taxi-fare from Canaan, plus the ability to carry 20-litres of fume-emitting paraffin - a combination not available to the ten women in the group. Over 50% of the paraffin used by 350 households at Canaan was bought from the spazas[3], and the women in the group numbered among those who bought small amounts of paraffin (between 500 ml and 1 500 ml) on a daily basis. Usually a child was sent to the closest spaza to buy the daily ration, so that the women were largely unaware of the price variances among spazas until they were brought up at the weekly meetings.

Zodwa explained why she bought paraffin every day:

> If I buy only one bottle of paraffin and one candle a day, I use only that amount, so I am disciplining myself. Also, if I have only some few cents, I must buy some food, some paraffin, one candle and maybe something to drink.

Her explanation encapsulated the juggling and balancing required of women as household managers every day. The other members of the group affirmed Zodwa's reasoning and their daily logging schedules confirmed that bread, paraffin and candles were bought daily. Average weekly expenditure on fuels amounted to 20% of each household's income. Relative to their incomes, the women's complaints that fuel was expensive were justified.

Appliances

The ten women in the group used single-burner primus or wick stoves because they cost R20 as opposed to R30 for a double-burner primus stove. They complained that single-burner primuses lasted only about three months before the wick needed replacing, or they simply "collapsed". One of the problems with the more expensive stoves was that, although they lasted twice as long, they were expensive to repair. Also, R30 was a third more difficult to accumulate than R20. (This perceived negative feature should be balanced against the actual efficiency of the appliance, which is in the relatively high order of 50%.) The women also expressed irritation at the limitation of being able to cook in only one pot at a time on a single-burner primus stove. It was inconvenient and expensive as it seemed to devour all the paraffin each time. Nolwazi articulated her frustration thus:

> Sometimes a litre of paraffin cooks only dried beans, and cooking bread uses a whole litre. Before the day ends I use two litres of paraffin cooking in just one pot all day.

**** Personal observation and record, 1 March 1991.

(Again it should be noted that primus stoves are easier to maintain at a constant low heat than a fire, and for this reason are well suited to simmering as required above.)

Food or fuel?

If a woman cannot plan ahead because she is uncertain of her income that day, and has "only some few cents" with which to juggle, she has to decide whether she buys food or fuel first, and when it comes to fuel, whether she buys wood or paraffin. Discussions in the women's weekly meetings revealed a number of variables at play in complex combinations, only two of which are discussed here.

Beans and bread were commonly cooked when there was very little money because both were enjoyed by the whole family who then did not notice (so much) that their favourite food (meat and samp or mieliemeal) was too expensive for that day's allowance. But this may, as Nolwazi pointed out, involve the consumption of two litres of paraffin in addition to the ingredients, and would cost the equivalent of buying meat and cooking it on a fire outside. However, this would imply a walk to the butcher (there were no fridges at Canaan), a further walk to the dump or the bush to collect wood, and the tediousness of making a fire. This involved a great deal more physically tiring and time-consuming work than buying beans and paraffin from the spaza, and usually, the women agreed, was not worth the effort because it was not as filling as beans and bread.

Particularly interesting was the regularity with which women said, "I had no money so I cooked bread today". Bread was made with a small packet of flour, salt, a raising agent (such as, sour milk, beer or yeast) and water, boiled in a strong plastic bag for over an hour, consuming a litre or more of paraffin. The combined cost of the ingredients plus the paraffin was twice that of a standard loaf of bread - even one bought at an inflated price at a spaza shop. When asked, "Why do you make bread?", the responses indicated that it was not the cost that was the first consideration.

> The bread we make is so nice. It is so nice if a woman makes bread and it's not too much work. First you mix the dough, then you have to wait a long time for it to rise if you use yeast. Then you have to find one or two packets# that don't have holes. You put the well-risen dough inside and tie it up securely so it doesn't get wet and gets crusty. Then you boil it on the stove for an hour and it smells good. Then when it's ready it's all hot and steamy and smells good and the children will just say "Ooh, Ma, you've made bread", and eat the whole lot and go to sleep without asking for more.

(# Since the women do not shop at supermarkets where carry-bags are supplied, plastic bags are a scarce and valued commodity at Canaan.)

Thus it was not so much the amount of money spent on making bread that was important, but the implications of satisfying mothering and housekeeping. The time and effort invested in making bread had its rewards in the "good motherliness" and gratifying cessation of demands. The expense and inconvenience of paraffin, although an irritation, did not appear to be a major consideration. In addition, the woman did what she believed she could manage - "it's not too much work".

"The cost of energy, both in terms of money and physical effort is enormous for most, paralysing for some."

On another occasion a woman explained to the group how she overcame the limitations of a single-burner and still fed her family nutritiously by cooking samp and then adding vegetables to the same pot to make a stew[7]. The suggestion of the stew was a resounding success with women in the group and their friends. Subsequently they reported that they were using a variety of vegetables and greens, and that they were pleased that their children were eating vegetables without complaining*****.

Fuel purchase and income

Although daily household incomes were not specifically monitored in this study, indications were that the form in which income was derived was an important factor in decision-making and budgeting. Whether a woman receives her household budget in one large sum monthly, smaller sums each week, or "some few cents" every day (or every few days) affects her choices and the decisions that she may make. The women articulated the anxiety they felt as a result of being uncertain both about the length of the interval between receiving any income and the sum anticipated. In terms of this anxiety it was considered prudent to spread the income over a variety of commodities rather than spending one day's full allowance on, say, 20 litres of paraffin. On the other hand, the two women in the group who received a weekly allowance were immediately in a position to buy a packet of six candles and save accordingly.

Conclusions

Fuel and food accounted for a large proportion (about 60%) of the incomes of the ten participating households, and the available incomes were managed primarily by the women who budgeted strategically according to their households' perceived needs. The women in the group purchased small quantities of relatively expensively priced fuel according to their daily income. Households whose incomes were low and unpredictable were unlikely or unwilling to spend more than approximately R2 a day on domestic fuel. The cost of the fuel was an important but not a determining factor in the decisions made about food by the ten women each day. Convenience as well as the perceived physical and emotional well-being of the women and their households were equally important. However, these choices were made within the constraints of the limited income "in hand".

However much the ten women disliked paraffin it is doubtful whether, under their present circumstances, they would be able to afford unsubsidised electricity or appliances. Electrification schemes may not be viable unless both the energy and the appliances are subsidised, and unless methods can be designed whereby users in the category of the ten Canaan households are enabled to make payments in small, regular amounts as currently happens with the purchasing of wood and paraffin.

***** The relationship between fuel, food and nutrition warrants more rigorous examination. This has been attempted in a follow-up study currently in progress.

Paraffin may be an inferior source of domestic energy in terms of quality but it is superior in terms of convenience. As a liquid it is able to be distributed in bulk and dispensed in amounts suitable for differing customer requirements, thus accommodating both the women's short-term ("live for today") needs and the practical constraints imposed by daily budgeting. The distribution of paraffin through a complex network, including spazas, renders it accessible in terms of distance (children can be sent to buy it) and quantity to suit low-income households.

The issue of appliances is a vexed one and of paramount importance in the transition from one energy source to another. The transition to higher order fuels is constrained by the dramatic leaps in cost of both fuel and the corresponding appliances. The relative affordability of paraffin liquid and appliances, in conjunction with their accessibility, efficiency and convenience compared with other sources of domestic energy, suggest that it is likely to continue to be used extensively - at least in the short to medium term future.

In this event there is substantial room for paraffin producers to improve their product before they can boast of satisfied customers. Poison by swallowing or toxic fumes, skin irritations, the unpleasant smell and residual grime from burning, all need to be researched and addressed without raising the price to consumers. The ripple effect of any increase in the price of paraffin would be disastrous to the already overburdened poor.

Despite the group's negativity towards paraffin, it is used consistently in preference to wood. In this transitional phase, women's use of lower order fuels is determined largely by the harsh realities of poverty. Paraffin reduces the arduousness of women's domestic tasks considerably.

Finally, energy in the form of domestic fuel plays an important role in the lives of the women's group at Canaan, but energy in the form of the ability to act, plays a crucial role. The cost of energy, both in terms of money and physical effort is enormous for most, paralysing for some. There can be few better illustrations of what may be implied in the phrase "the quality of life" than observing the efforts expended by the women in the group to meet the basic needs of their households. The women's willingness to share experiences and discuss issues revealed some of the complex variables pertaining to decision making and led to small adjustments in daily schedules as well as experiments such as the successful "mixed stew pot" cooked with one litre of paraffin on a single-burner. The household management strategies employed by the women in the group have their own rationality which warrants further investigation and understanding, and should be taken into careful consideration in the planning of a "woman-friendly" national energy policy for a future South Africa.

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References

(1) BERNSTEIN A (1990). Signposts. *Leadership*, Vol.9, June, p.18.

(2) ANNECKE W (1992). We are so poor: An investigation into the lives of ten women living in an informal area in the Durban Functional Region, with particular reference to the role of domestic fuels. Unpublished University of Natal M.A. thesis.

(3) ARDINGTON E (1992). Buckpassing in Canaan: An example of authorities' failure to address the needs of informal urban dwellers. Rural Urban Studies Working Paper No.24, Centre for Social and Development Studies, University of Natal (Durban).

(4) NDUKWANE G, MEMELA T, PHAKATI D and QWABA T (1993). No space to plant: Stories told by women from Canaan. New Readers Project, University of Natal (Durban).

(5) NATIONAL ENERGY COUNCIL (1992). Annual Report 1990-1991. National Energy Council, Pretoria.

(6) ROSS F (1991). Personal communication. Department of Social Anthropology, University of Cape Town, November.

(7) MKHIZE S (1991). Personal communication. Women's group, Canaan.

Household energy use in South Africa, air pollution and human health

*** A P S TERBLANCHE, * * I R DANFORD and * * * C M E NEL**

The environmental health problems associated with the use of household energy sources which are low on the energy ladder (high adverse impacts, low-efficiency and low-cost) are covered in this paper. Extensive research has been undertaken by the CSIR, the Medical Research Council and the Department of Mineral and Energy Affairs, to characterise human exposures to air pollution, generated by the most commonly used household energy sources in South Africa, namely, wood and coal. The results of studies performed in Sebokeng, Vaal Triangle and in the Marble Hall district, north-eastern Transvaal, indicated that human exposures to air pollution caused by household use of wood and coal exceeds health standards by factors of 2-10. The levels documented are dangerous to health. Risk factors for higher exposures identified were season (winter), gender (boys), non-electrified areas (versus partially or completely electrified urban areas), and stove types (braziers). The urgency for introducing cleaner household energy sources into non-electrified households in South Africa is emphasised in this work.

Keywords: household energy; air pollution; health; fuelwood; coal; transitional fuels; fuel use; stoves

Introduction

The World Health Organisation (WHO) has estimated that up to 90% of household energy supplies in Sub-Saharan Africa comes from fuels which are low on the energy ladder (low-cost, high environmental and health impacts)[1]. In South Africa, approximately 60% of the population have to depend partially or completely on coal or wood for cooking and space heating.

Traditionally, air pollution has been associated in many people's minds with industrialisation and urbanisation, and thus most air pollution control and management programmes to date have been introduced in the cities of developed countries[2]. In recent years, however, it has been demonstrated that the worst ambient air pollution conditions prevail in the cities and townships of developing communities[1,2]. Multiple pollutants, both gaseous and particulate, can be emitted as a result of wood- or coal-burning. These pollutants are typically emitted in the indoor environment from stoves which are unvented or poorly vented, causing a build-up of pollutants inside the home. Pollution build-up in these micro-environments can reach levels which exceed health standards by factors of 10-20 or more[3]. Because of such high concentrations and the large number of people exposed, the total human exposure to air pollution is more substantial in the homes of the poor in developing communities than in the air of cities in the developed world[3,4]. The health risks associated with such exposures are profound and are a major concern across the globe. Apart from the health impact, preliminary indications are that household energy use may also contribute significantly to global greenhouse gas emissions[5].

"In recent years, however, it has been demonstrated that the worst ambient air pollution conditions prevail in the cities and townships of developing communities."

Total human exposures to air pollution from wood- and coal-burning in developing communities within the developed regions of South Africa have not been well characterised. Results of ambient air pollution measurements alerted the authorities and communities to possible extensive exposures[6,7]. This led to a number of research projects which endeavoured to characterise total human exposures to gaseous and particulate pollutants from wood-burning in rural areas of the Transvaal Highveld, as well as from coal-burning in Sebokeng in the Vaal Triangle. The results of some of these exposure monitoring studies are conveyed in this paper.

Methods

This paper focuses on results obtained in households using coal and wood for cooking and space heating. Both gaseous and particulate pollutants were monitored in pre-selected households. The methodologies of the rural wood-burning and the urban coal-burning projects are discussed separately.

Rural wood-burning data collection

A survey was undertaken to monitor the levels of gaseous and particulate pollutants in homes using wood as fuel for space heating and cooking during July 1992 in the Marble Hall district.

Selection of study area

Criteria used to select the study area included: (a) use of wood as a household energy source; (b) the rural area had to be situated in a severe winter temperature zone; and (c) building structures had to be representative of areas in the cold winter rural areas of South Africa. Based on these criteria, a farm in the Marble Hall district on the Transvaal Highveld

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(1 400 m above sea-level, savanna-type environment, with dominant agricultural activities) was selected for the monitoring programme. Following permission being obtained from the farming community, which consisted of 34 households, the monitoring programme commenced.

Pollution monitoring procedures

Gaseous pollutants were monitored continuously over an 8-hour period, starting from 09h00 or 14h00, to include the peak exposure time associated with cooking processes. Due to the unavailability of electricity, battery-operated monitors had to be used, limiting the monitoring period. Sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO) were monitored, using an electrochemical Exotox Model 75 continuous monitor. The lowest detection limit of the monitor is 0,1 parts per million (ppm).

Total suspended particulate (TSP) matter was monitored using a Gill Air model 224-X R pump, sampling at 2 l/min. over a 12-hour period (08h00 until 20h00). Cellulose filters were chosen to enable X-ray fluorescence elemental analysis to be performed (glass fibre filters present a problem because of their chemical composition). Gravimetric analysis was performed using standard procedures[3]. Quality control/quality assurance procedures included careful inspection of filters for irregularities and re-weighing of a statistically significant sample. A specially equipped weighing-room with a temperature and humidity control system was used.

Sampling sites

Monitoring and sampling of all pollutants were performed inside the cooking areas, while TSP readings were taken inside the sleeping areas as well (these were separate buildings attached to the cooking huts). Personal TSP monitoring was also performed, using 15 children aged 8-12 years. Personal monitoring commenced at 08h00 and lasted for 12 hours. The methodology of personal monitoring is given below as part of the urban study methodology.

Urban coal-burning data collection

During the winter of 1992, a similar survey was undertaken to measure the levels of gaseous and particulate pollutants inside homes using coal for cooking and space heating. Personal monitoring was conducted during the summer and winter of 1992.

Selection of study area

Fifteen homes were selected in Evaton, a township neighbouring Sebokeng in the Vaal Triangle. The single most important selection criterion was the absence of electricity in the specific zone selected for the study. All homes were confirmed to be coal-burning households.

"The unavailability of electricity is therefore an additional risk factor for exposure to hazardous levels of air pollution."

Monitoring procedures

The same pollutants were monitored using exactly the same methodology as for the rural study. Stationary monitoring was performed inside the cooking areas only.

Personal monitoring procedures

Pupils from the Sebokeng area (partially electrified townships in the Vaal Triangle) were solicited through the regional health clinics to participate in the study. The participants were selected from the group who participated in the Vaal Triangle Air Pollution Health Study (VAPS) and for whom a health questionnaire had therefore been completed[8]. Information on parental smoking, household characteristics, location of home, socio-economic status and respiratory tract symptoms were available for each participant.

The methodology of the study, as well as the rural personal monitoring study, is described. Informed consent was obtained from each participant's parents, after which participants were trained and informed about the requirements for carrying the monitor. An interpreter was used to facilitate communication. Maximum co-operation was requested, and participants were instructed to follow their normal daily activities while carrying the monitor. Light-weight monitors (Gill Air model 224-X R) were carried by the participants on various days during the summer and winter. Monitoring was done on a school day and one day (Saturday) over a weekend during the summer, and on a school day and non-school day (also a week-day) during the winter, in partially electrified areas (using electricity mainly for lighting and coal for cooking and heating). The same group of children were used for all the monitoring days, except the summer weekend day where a different group of children was used. These children were selected randomly from two different areas, a completely electrified area and a non-electrified area close by respectively. Monitoring was done at a flow-rate of two litres per minute. Glass fibre filters, housed in open-head containers and worn within the breathing zone of the child, were used to sample the particulate matter. This type of filter is more robust and less sensitive to humidity and does not affect the method of collection nor the validity of the data, but can effect secondary analysis, such as, XRF elemental analysis. Total suspended particulates (TSP) were sampled and not only the respirable fraction. The monitoring period was scheduled for 12 hours, starting at 08h30 and ending at 20h30 on each of the monitoring days. The monitors were switched on by field personnel, while the participants switched them off at the end of the monitoring period. The monitors recorded the exact monitoring time. Acclimatisation of the filters, as well as gravimetrical analysis, was done according to the standard procedures of the South African Chamber of Mines, adopted from NIOSH.

Statistical analysis, using Wilcoxon tests, was used to compare seasonal and day-of-the-week variations in exposure levels. The following groups were compared: summer vs. winter exposures overall, days of the week (school vs. non-school), boys vs. girls, and partially electrified vs. non-electrified areas.

Results

The results of the stationary indoor monitoring for the rural and urban environments are given separately from the personal exposure monitoring results.

Table 1 summarises the maximum hourly averages measured for SO_2, NO_2 and CO in wood- and coal-burning homes. The measurements were all taken in the cooking area of the homes monitored during the winter of 1992. In the case of SO_2 and CO emissions, levels were documented which exceed the health standards in 24% and 4% of cases respectively in the coal-burning households, and 34% and 11% in the wood-burning households respectively.

The 12-hour average TSP levels measured inside the coal- and wood-burning households are summarised in Table 2. In all cases, measurements taken in both wood- and coal-burning households were above the U.S. health standard of 260 micrograms/m^3. The WHO no-effect-exposure limit (180 micrograms/m^3) was also exceeded in all homes[3,4]. As the methodology used in this study is different from high volume sampling, which is the standard method that relates to the 24-hour TSP health standard, it is not possible to make a direct comparison. However, based on personal monitoring, the exposure limits are taken as 1/50th of the threshold limit of 10 mg/m^3 for an 8-hour average. This is done to allow for the increased sensitivity of the general population, which includes children and the elderly. The proposed exposure limit is therefore taken as 200 micrograms/m^3 (50 times below the occupational limit of 10 mg/m^3), which is below the U.S.A. 24-hour health standard of 260 micrograms/m^3.

Comparisons between TSP levels indoors, when braziers were used instead of stoves, indicated a clear trend in higher exposures associated with the use of braziers (934 versus 603 micrograms/m^3 12-hour averages).

The results of personal exposure monitoring in the rural wood-burning farming community (n = 15 children) indicated exposures varying from 1 044 to 8 330 micrograms/m^3 (average 2 367). The personal TSP exposure monitoring results from the urban coal-burning area over a 12-hour period varied from 294 to 2 304 micrograms/m^3. The average 12-hour exposure during a summer day (08h30 - 20h30) was 662 micrograms/m^3 (n = 15) compared with 1 333 micrograms/m^3 for a winter school day (n = 13). The difference was highly significant ($p<0,0002$). Comparisons of exposures related to specific potential risk factors, such as season and gender, indicated significant differences in exposures for the following factors: season (winter higher than summer), gender (boys higher than girls), day of the week (school days higher than non-school days). Schools in Sebokeng are situated in the centre of completely non-electrified areas. Statistically significant differences between personal exposures to TSP were also documented for children living in electrified vs. non-electrified (coal only) areas. The unavailability of electricity is therefore an additional risk factor for exposure to hazardous levels of air pollution.

CONCENTRATION FOR EACH HOUSEHOLD TYPE+				
POLLUTANT++	COAL	N	WOOD	N
SO_2	1,83	15	5,08	18
NO_2	0,46	15	0,09	18
CO	145,00	15	80,40	18

\+ Concentrations are given in parts per million (ppm).

++ The hourly health standards for the three pollutants are: SO_2 0,40 ppm; NO_2 0,60 ppm, and CO 35 ppm.

Table 1: Maximum hourly averages for specific pollutants measured indoors in wood- and coal-burning households

12-HOUR AVERAGE LEVELS OF TSP			
FUEL TYPE	N	MICROGRAMS/M^3+	
Wood			
Cooking area	20	1 725	(814 - 3 985)
Sleeping area	6	1 023	(728 - 1 799)
Coal			
Cooking area	27	750	(161 - 1 568)

\+ The 24-hour U.S. health standard is 260 micrograms/m^3

Table 2: Concentrations of TSP measured inside coal- and wood-burning households in South Africa during the winter of 1992

Discussion

The availability of air that is safe to breathe is as important as safe water and food. For Africa as a whole, it is estimated that 90% of the population is breathing air which is not safe[9]. In South Africa, the best estimate is 20-25 million people (60% of the total population). The results of the research projects reported here support the concerns raised by the WHO about Africa, including Southern Africa[3]. The levels of SO_2, CO and TSP documented in homes of South Africans who have to rely on wood and coal for space heating and cooking, are similar to levels in reports from Kenya, Zimbabwe, Gambia and India[2,3,4,9,10]. Apart from the single pollutant effects well-described for SO_2, for example, is the synergistic effects known to exist between SO_2 and particulate matter (TSP), an additional cause for concern. In 100% of the homes monitored, TSP levels were a factor of 3-8 above the health standard, while in 24-34% of the homes the SO_2 levels also exceeded the health standards with factors of 2-10. The TSP levels measured over a 12-hour period were so high that they even exceeded 24-hour exposure guidelines. Carbon monoxide was, in some cases, more than double that of the hourly health standard. The levels of air pollution documented indoors are of particular importance as these are the micro-environments where infants and children spend most of their time.

Total exposures of children to TSP monitored over a 12-hour period using personal exposure monitors, also revealed that levels exceeded all health standards 100% of the time, even in summer, the "low" pollution period. The risk factors for higher exposures identified by the current research projects, include the winter season, boys, non-electrified areas, and the use of braziers indoors. More information on risk factors which can be managed to reduce the risks is currently being collected.

Although there is still much more to be learned about the health risks of "dirty" household fuel usage, there is sufficient information to know that the adverse effects should not be underestimated. Research in Sebokeng has already identified coal usage as the single most significant determinant of respiratory diseases in children aged between 8-12 years[8]. Furthermore, recent epidemiological data have indicated that acute respiratory infections (ARI) are one of the leading causes of death in black South African children[11]. The mortality rate of ARI in South Africa is 270 times greater than for children in Western Europe. The data reported here emphasise the concern about the health impact of household fuels on community health in South Africa, and, ultimately, the economy of countries which cannot afford it. The complexity of the problem, which is a socio-economic one, makes quick solutions impossible. It is, however, of prime importance that, parallel with the development of cleaner fuels and increased electrification, data be collected on risk factors such as stove types, ventilation, risky behaviour etc., to enable a risk-based decision-making process to be used to formulate an acceptable household energy policy for South Africa.

Acknowledgements

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References

(1) WORLD HEALTH ORGANISATION (1991). Indoor air pollution from biomass fuel. WHO/PEP/92.3A, Geneva.

(2) SMITH K R and LIU Y (1992). Indoor air pollution in developing countries. *In*: Samet J M (Ed.). The epidemiology of lung cancer. Marcel Dekker, New York (Forthcoming).

(3) SMITH K R (1987). Biofuels, air pollution and health: A global review. Plenum Press, New York.

(4) SMITH K R (1988). Total exposure assessment: Implications for developing countries. *Environment*, Vol.30, pp.16-20.

(5) SMITH K R and THORNELOE S A (1992). Household fuels in developing countries: Global warming, health and energy implications. *In:* Proceedings of the 1992 Greenhouse Gas Emissions and Mitigation Research Symposium, New York.

(6) SITHOLE J S, TURNER C R, LYNCH E, RORICH R and ANNEGARN H (1991). Air pollution exposures in coal burning residential areas of South Africa. *In:* Proceedings National Association for Clean Air, Durban.

(7) TERBLANCHE A P S, OPPERMAN L, NEL C M E, REINACH S G, TOSEN G and CADMAN A (1992). Preliminary results of exposure measurements and health effects of the Vaal Triangle Air Pollution Health Study. *South African Medical Journal*, Vol.81, pp.550-556.

(8) TERBLANCHE A P S, NEL C M E and OPPERMAN L (1992). Health and safety aspects of domestic fuels. Report to the Department of Mineral and Energy Affairs. Report No. NE 14/6/30/

(9) LEACH G A (1988). Residential energy in the Third World. *Annual Review of Energy*, Vol.13, pp.47-65.

(10) BOLEIJ T S M, RUIGEWARRD P and HOEK F (1989). Domestic air pollution from biomass burning in Kenya. *Atmospheric Environment*, Vol.23, pp.1677-1681.

(11) VON SCHIRNDING Y E, YACK D and KLEIN M (1991). Acute respiratory infections as an important cause of childhood deaths in South Africa. *South African Medical Journal*, Vol.80, pp.79-82.

Energy news in Africa

Electricity

A feasibility study for a R4,7 billion, 1 600 MW hydroelectric power plant on the Zambezi River, is to be undertaken by the Zambezi River Authority. The power plant, which is expected to be operational before 2003, is to be constructed on the Batoka Gorge between the Victoria Falls and Lake Kariba, and will be shared by Zimbabwe and Zambia.

The feasibility study has looked at the power system, power planning and reservoir operations, optimisation of dam and machine sizes, geology, environment, cost estimates, and financial and economic analyses.

(Source: Engineering News, 18-22 April 1993)

The Kihansi hydropower project, on the Kihansi river near Ifakara in central Tanzania, is planned for construction between 1993 and 1998. The project is part of the Power VI programme financed and co-ordinated by the World Bank in late 1991. An initial capacity of 180 MW is proposed from three 60 MW Pelton units at a cost of approximately US$220, including transmission lines.

(Source: International Water Power & Dam Construction, March 1993)

Electricity - Eskom

Eskom has signed a co-operation agreement with the China Light and Power Company (CLP) of Hong Kong. The agreement covers the exchange of information, expertise and technology between the two utilities. Both use coal, nuclear power and hydroelectric generation technologies to produce electricity. Plant used at CLP's Castle Peak power station is similar to that used in Eskom's Matla, Duvha, Tutuka and Lethabo power stations.

Eskom has already signed an agreement with the Hong Kong Nuclear Investment Company (HKNIC) and the Guangdong Nuclear Power Joint Venture Company (GNPJVC). In terms of this agreement, Eskom is assisting with the commissioning and operation of their twin-reactor nuclear power station at Dava Bay. Work is at the stage where nuclear fuel will soon be loaded into the first reactor. The nuclear installation was designed by the French company Framatome and is similar to that in use at Koeberg. The Dava Bay project is the first major joint venture between Hong Kong and Eskom in the field of nuclear power generation.

(Source: Eskom Press Release, 27/4/93)

Dr Ian McRae, Chief Executive of Eskom, has been elected president of the World Association of Nuclear Operators (WANO). Eskom has been a member of WANO since the building of Koeberg. Dr McRae's appointment, which runs for two years, is regarded as a major breakthrough for Eskom and South Africa in the ranks of nuclear operators.

(Source: Eskom Press Release, 23/4/93)

Mr Allen Morgan, 45, has been appointed as the new Chief Executive of Eskom to succeed Dr Ian McRae who retires in March 1994.

Mr Morgan is presently the Executive Director of Eskom's Sales and Customer Service. He is responsible for the distribution of electricity and Eskom's electrification programme.

(Source: Eskom Press Release, 20/4/93)

Sasol

Sasol is planning six new projects which will be worth over R1,5 billion. These projects are in addition to eight projects already disclosed to be worth R5 billion, which are to be started over the next five years. Funds for these projects would come from internal resources. The new projects are expected to achieve real earnings growth from 1993/94 onwards.

The new projects excluded the Pande gas field development project in Mozambique and the oil exploration project off the Namibian coast, which were announced last year. Among the new projects awaiting approval are: a R300 million ETBE/MTBE plant; a R600 million investment in coal mining for the export market; a R120 million isomirisation unit for a crude oil refinery for the production of unleaded fuel.

(Source: Business Day, 19/4/93)

Engen

Engen Limited is to spend US$266 million to upgrade its 65 million barrels/day (b/d) Genref Refinery in Durban. The goal of the upgrade is to improve the yield of high-value fuels and to reduce production of low-value bunker oil.

(Source: Fuel News, March 1993)

Mossgas

The Mossgas plant is now onstream. Output of gasoline, diesel fuel and illuminating paraffin is running at a third of the eventual 30 million b/d capacity which is expected to be reached in the third quarter of 1993 when all three reformer/Synthol unit trains are commissioned. Products are already being distributed in the Cape area, with future production of alcohols earmarked for the export market.

(Source: Fuel News, March 1993)

Southern Africa - Trade

The eleventh summit of the 19-member Preferential Trade Area (PTA) for Eastern and Southern Africa was held in Lusaka in January 1993. Aspects covered at the summit were: the completion of a draft treaty for the transformation of the PTA into a Common Market for Eastern and Southern Africa (COMESA) by the year 2000; confirmation of Namibia as the 19th member; the setting up of a ministerial committee to investigate relations with the Southern African Development Community (SADC); the adoption of a new single rate of tariff reduction of 60% and an agreed timetable for subsequent tariff reductions; the request for the dismantling of all non-tariff barriers to intra-PTA trade.

The summit held in 1992 had called for a merger with the SADC. However, the SADC stated that the two organisations have distinct objectives and mandates, and must continue to exist as autonomous but complementary entities. This is what the ministerial committee established at the 1993 summit is to investigate further.

(Source: AI Bulletin, Vol.3 No.3, 1993)

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