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RESEARCH PAPERS

2/1

ZIMBABWE INSTITUTE OF DEVELOPMENT STUDIES

**Issues and Prospects
In Coal Utilization
In Zimbabwe's Rural
Households**

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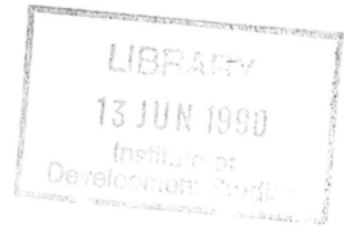
RESEARCH PAPER SERIES

Number 1

ISSUES AND PROSPECTS FOR COAL
UTILIZATION IN ZIMBABWE'S RURAL
HOUSEHOLDS

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We are grateful to all respondents who answered our numerous questions during the survey leading to this report. Our sincere thanks go to the management and respondents at Mazoe Citrus Estates, for their cooperation, to the Wankie Colliery Company and Lakas Products (Pvt.) Ltd. for sharing their ideas on coal and coal stove prices; to the local authorities at Shurugwi, Murehwa and Mberengwa for granting us access to their districts and for providing accommodation and other facilities to our enumerators. The same goes to the various schools which assisted in like manner.

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INTRODUCTION

The supply of energy to rural households in Zimbabwe has become an urgent issue for Government particularly for the reason that the traditional form of rural household energy, wood, is increasingly becoming harder to obtain due to the growing depletion of trees in most sections of the country.

A few options have been considered to guarantee the supply of energy to affected households and to curb any loss of trees that may be attributed to the energy applications of indigenous forests.

Among these options is the introduction of coal to rural households as a substitute for wood or as an alternative fuel where wood is no longer available.

In this regard both the Ministry of Energy and Water Resources and Development and the Wankie Colliery Company are attempting to introduce coal into rural households. Currently, Wankie Colliery have sold about 270 stoves to rural users, the Department of Energy have introduced 135 coal stoves into the rural areas largely for experimental purposes. Lakas, a coal merchant company, has sold about 207 stoves throughout the country since 1985.

All these attempts to introduce coal to rural households are being made in the absence of a clear understanding of some of the factors which might influence the effective diffusion of coal as a fuel in the rural households. Lack of such information may retard the dissemination of an otherwise highly acceptable and manageable technology or may allow the wastage of scarce resources and effort on an undesirable technology.

Our work in this paper seeks to assist Government and the coal industry by providing a studied background to the idea of making coal a basic household fuel in Zimbabwe and in doing so to fill this information gap. The paper reports the results of a study conducted specifically for this purpose.

The study assesses in general the degree to which coal can be a successful alternative to woodfuel or can offset the energy deficit caused by woodfuel depletion in the rural areas. In this regard the study assesses those attributes of coal which may affect its acceptability in rural households. These factors include cost, hazardous emissions, smoking, handling, and conformity or lack of conformity with entrenched energy use patterns and lifestyles on the one hand and rural households attitudes towards coal, their incomes, cost of coal, and attitudes toward the idea of commercial fuels on the other hand.

The study takes a two-pronged approach to the assessment of health risks associated with coal burning in the rural household setting. First, the design of cooking devices and of the cooking environment, the kitchen, are analyzed for the purpose of determining the possibility of harmful exposure to toxic emissions due to poor dispersal of harmful emissions from coal. Second, the study analyses the properties of the coal most likely to be used in rural households with the view to assessing the quantity of hazardous substances it is likely to release during burning in the household.

The study also reviews the structure of delivered prices for coal at selected villages or districts. This is done by reviewing existing and possible coal price build-ups. Consideration is also given to the option of small-scale coal mining as a means of bringing small mining operations close to the woodfuel deficient areas as a means of reducing the price of coal delivered to households.

Four areas (districts) were chosen for the survey. These are Mukarakate in Murehwa, Tongogara in Shurugwi, Chingezi in Mberengwa, and the Mazowe Citrus Estates. The first three of these areas face a severe shortage of fuelwood. The Mazowe Citrus Estates have no fuelwood shortage but have been using coal in their households for over 20 years. Mazowe thus presented a good case for judging the adaptability of households to coal as a basic fuel and also to determine any actual difficulties households may have experienced in using coal.

Target Population

In Mberengwa and Shurugwi the population was randomly selected, irrespective of whether one had or had no coal stove. In Murehwa a list of all households with coal stoves was obtained from the Ministry of Energy and Water Resources and Development. An attempt was made to survey all these households.

Mazowe Citrus Estates has over 30 villages. Our sampling was done in four of these villages selected on the basis of the occupations of their residents as shown below:

Table 1
SAMPLING AREA

Village	General Occupation of Residents
Yarrowdale	Citrus Production Workers
Hamilton	Crop Production Workers
Lawrencedale	Crop Production Workers
Central 2	Administrative Personnel

About 50 households were interviewed from each of the Mazowe Citrus villages.

In all districts the majority of the questionnaires were administered on women. This was a deliberate bias based on the leading role women play in the provision of household energy in the rural areas: This despite the possibility that roles may change once the household energy becomes fully commercialized and men as breadwinners take an increasing role in ensuring energy supplies.

PRESENT EXTENT OF COAL USE IN STUDIED AREAS

Currently 72 000 tonnes of coal per year are used as household fuel throughout the country. Of this quantity, 40 000 tonnes are bought by institutions for use in employee households. Coal use in rural households was difficult to estimate. The highest level of rural household utilization so far detectable is 10 tonnes sold from a distribution point at Murehwa for the year 1987. The Mazowe Citrus company supplies 90 kg of coal to each household per month (or just over a tonne a year) and provides the stoves free.

Of the 799 households interviewed, 226 (28%) owned coal stoves. Some 81 respondents have used coal stoves for more than five years. These were mainly in the Mazowe area and a few in the communal areas who had bought dover-stoves over 15 years ago. One

hundred and sixteen (116) respondents had owned stoves for a period of between 2-5 years. The other 29 households who have had their coal stoves for less than two years tended to be mostly those supplied by a third party under an experimental project.

If we excluded the Mazowe households, only 36 households (4.5%) of the surveyed total have coal stoves. Of the 36 households, 22 paid for the coal stoves on their own. Two households were supplied by Non-Governmental Organisations.

Direct purchase of coal stoves by rural households has not been a significant mode of diffusion in recent years. There are various reasons for this state of affairs. The survey indicates that three of these – lack of internal or external initiative, lack of exposure or general access to both stoves and coal and the cost of both stoves and coal – are the primary and the most common reasons for the low level of direct purchase of stoves by households.

A significant number of the households responded that they had not thought of or been informed of the coal and coal stove option. Seven percent specifically said they had not heard of coal stoves and a few admitted not knowing what coal was while others admitted not having seen coal before.

Others indicated that coal stoves were not available in the rural areas and that even if they purchased the stoves they were not sure they could be guaranteed supplies of coal consistently and at an affordable price.

Forty percent of the households specifically cited cost as the major reason why they would have reservations about coal as a fuel option.

There were various other reasons for the slow progress of coal diffusion.. These are discussed below. The shows, however, that these other reasons do not override the three major causes of slow diffusion described above.

PERCEPTION OF HAZARDS

On setting up this project we had expected that the perception of coal as a hazardous fuel would have a significant effect on the attitude of rural households to the use of coal as a household fuel and thus contribute to its low acceptance. The survey findings were contrary to this initial view. First, the majority of the respondents, 62%, were ignorant of the hazards of coal utilization as a household fuel. Only 4% of the people interviewed expressly said they preferred wood to coal because coal was hazardous to health. This, though, was just an expression of preference. None of these respondents said they would categorically refuse to use coal because of the perception of hazard even after some cases of coal poisoning were recounted to them. Statistical analysis of the survey data showed very poor correlations between the perception or awareness of hazard and variables measuring the respondent's predisposition to accept coal.

However, those respondents who knew of the hazards of coal tended to associate coal fumes with toxification, headaches, and coughs.

TRADITIONAL/SOCIAL CONSIDERATIONS IN THE INTRODUCTION OF COAL UTILIZATION IN RURAL HOUSEHOLDS

The study considered the acceptability of coal in view of the traditional attributes of a household fire. Questions asked related to the cooking practices of households, the heating properties of coal, its smoking properties, and its ignition difficulty. As stated earlier, a large number of the households interviewed, 49%, had no experience with the use of coal whatsoever. Some did not even know what coal was. Judgement on the utility of coal, thus, came mainly from people at the Mazowe Citrus Estates, a few households who had stoves in the surveyed districts, and from households with experience from previous non-rural situations.

Of the 404 respondents who had experience with coal, 293 generally preferred coal to wood as a household fuel. Sixty households believed that coal cooked faster than wood; 49 expressly noted that coal was more economical in terms of heating efficiency than wood; only 38 respondents preferred coal specifically because wood was getting scarce; 38 other respondents expressed the feeling that coal stoves were easier to use than wood during cooking; 32 others preferred coal because it emitted less smoke in the kitchen than wood. One hundred and eleven respondents preferred wood to coal. Eleven of these attributed their preference to the initial ignition difficulty of coal, 31 cited the toxic effects of coal; 31 others (out of the 404) cited cost as the reason they would not opt for coal. This low level citing of cost as the basis of preference of wood to coal should not, however, be misconstrued to mean that cost is not a major impediment to the diffusion of coal and coal stoves. Rather the question was asked specifically as an indication of preference or predisposition to accept coal in the background of a traditional and well entrenched fuel.

The survey also asked a general open-ended question to determine the preference levels for coal, all other things equal. In this regard respondents were asked simply if they would be happy to use coal. Eighty percent of the respondents answered yes. A few were indifferent. Those who strictly answered no were elderly people who explained that they were too old to start on a completely new cooking system.

THE EFFECT OF THE SHORTAGE OF WOOD

It was also initially thought that the shortage of wood would lead to a greater appreciation of coal as an alternative fuel. To estimate the shortage of wood the study used distance travelled by households to collect wood as a proxy. Long travel distances indicated greater wood shortage. Shorter distances indicated greater availability of wood.

Our initial expectation was to find a positive correlation between distance travelled (i.e. the level of wood shortage) and desire to use coal as an alternative fuel. The results of the survey were again contrary to our initial view: statistical analysis showed no correlation whatsoever between distance travelled and positive predisposition by households to use coal as an alternative fuel.

In fact, no particular variable was associated with the desire to adopt coal as a household fuel. We have thus not been able to determine, except in a few cases, the real basis for preferring or wishing to use coal on the part of the household. Perhaps the only explanation is that the fuelwood problem has become so generalized that the acceptance of alternatives

has become common sense. We also observed, however, that having a coal stove had a social status significance.

FURTHER ANALYSIS OF THE COST ELEMENT

We examine in this section the degree to which the cost variable is truly a significant consideration in the adoption of coal in rural households. Later we analyze the issue of the environmental implications of rural coal diffusion.

As a prelude we assessed the existence of attitudinal barriers to the commercialization of household fuel in the background of hitherto free uncontrolled fuel supplies.

We surveyed:

- the level to which households are familiar with the idea of purchasing fuel for their household use;
- the cost they were paying; and
- how long they had been paying.

Our findings were that experience with the purchase of fuel is limited. Of the surveyed population 24% paid for their fuel. Of those paying for fuel, 132 indicated that they had been paying for fuel for more than three years, 49 had been paying for up to three years and 11 people had been paying for a period of less than a year.

Eighty three respondents paid more than \$10.00 per month for fuel. About 100 respondents paid between \$5-10 per month. The rest of the households paying for fuel spent less than \$5.00 each a month on fuel.

These figures relate only to those households already paying for fuel. To measure the ability to pay for rural households in general we assessed the income base of the rural people to determine the degree to which it could support a commercial energy base for the households. The income base of the average rural household comprises basically agricultural product sales, with grain sales, mainly maize, contributing the bulk of the family income.

The general income structure for households in three of the surveyed communal area districts is shown in Figure 1.

Area specific income structures are indicated in Figures 2, 3 and 4. Mazowe Citrus income is basically salaries and is not represented in this analysis. Besides, income levels in this area do not affect the decision to use coal as coal and coal stoves are supplied free. The structure of income is basically the same in all the other districts except that at the time of the survey there was no food-for-work income in Murehwa. The bulk of the food-for-work income was in Shurugwi, with a lesser amount going to Mberengwa. Cotton sales featured very little in all cases and there were no cotton sales at all in the Shurugwi area.

Income per household averaged \$682 per year in Murehwa, \$402 per year in Shurugwi, and \$441 in Mberengwa. This translates to a per capita income of \$111 in Murehwa, \$49 in Mberengwa, and \$64 in Shurugwi for the survey year, 1987.

The incomes described above are very unevenly distributed throughout the year, peaking in July-August with grain sales and troughing about January - March after payments for school fees and seasonal planting costs.

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FIGURE 1
GENERAL HOUSEHOLD INCOME STRUCTURE
FOR MUREHWA, SHURUGWI, AND MBERENGWA

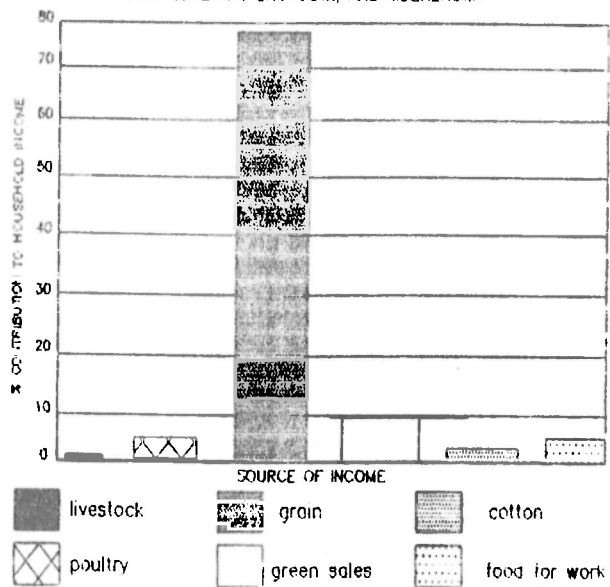


FIGURE 2
HOUSEHOLD INCOME STRUCTURE
FOR MUREHWA - 1987

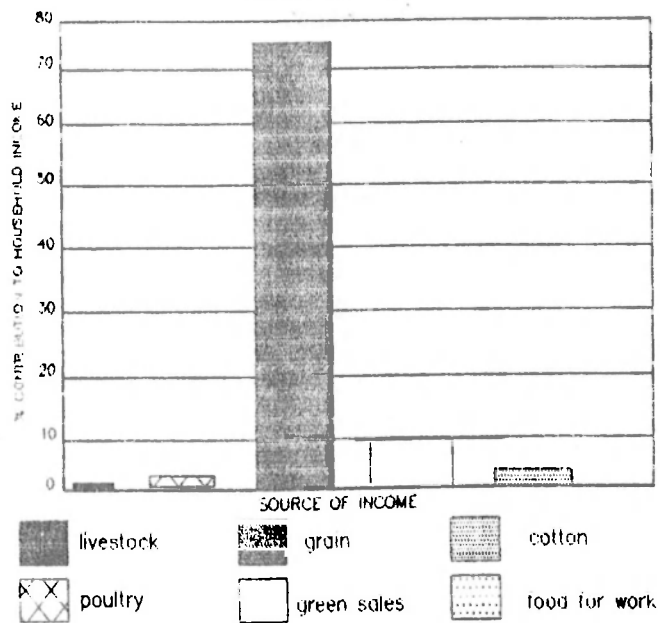


FIGURE 3
HOUSEHOLD INCOME STRUCTURE
FOR MBERENGWA - 1987

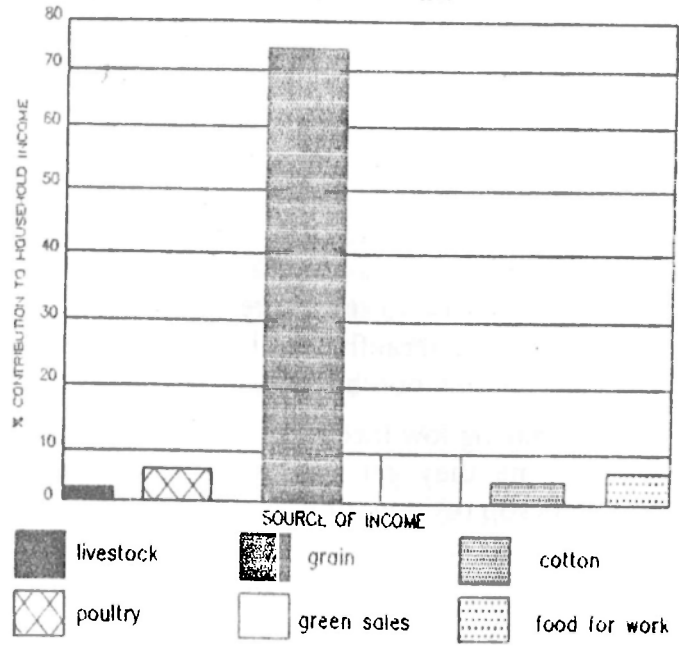
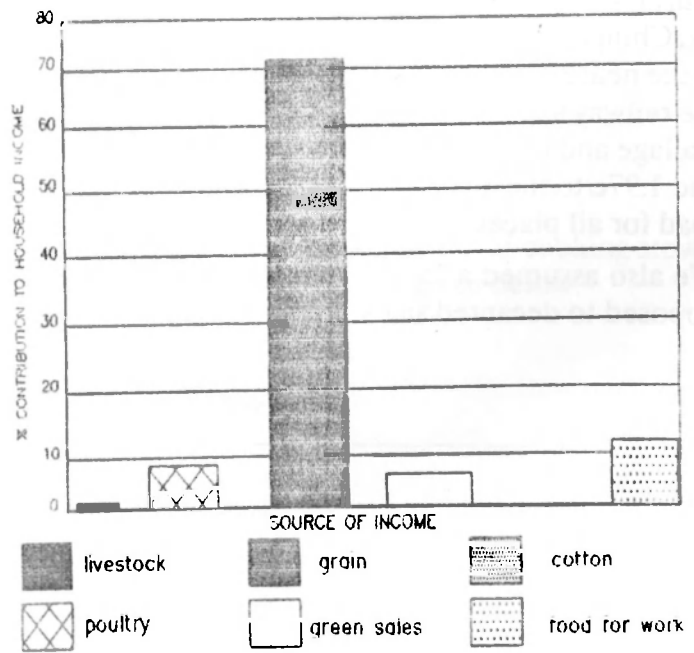


FIGURE 4
HOUSEHOLD INCOME STRUCTURE
FOR CHURUGWI - 1987



This seasonality of income also varies with districts. Income is less seasonal (more continuous) in those areas which have a higher income contribution from grain sales and poultry sales. In this regard Mberengwa has a less seasonal income structure than the other two communal area districts surveyed. If we included income from part-time work and repatriated income the seasonality graph would be flattened quite significantly in all the four areas with the greatest improvement occurring in Murehwa.

This seasonality of income also indicates that financial strain will reduce household ability to purchase coal during the low-income period – October through March i.e. six months of the year. It also happens that during the period of high income, April through August, rural households have less strain on their food budget and also benefit, albeit to a very small extent, from biomass from agricultural residues for energy. During this period, therefore, households would seek to substitute commercial coal with agricultural residue. It is not possible, given the general financial strain on the rural households, that money thus saved would be held for coal purchases later in the year.

Thus besides having low incomes, rural households also suffer from lack of continuity in the little income they get and disharmony between periods of low income and the availability of crop residue for energy.

THE COAL PRICE ELEMENT

The delivered price for coal will, of course, affect the ability of households to purchase coal and to adopt it as a base fuel. No data at the time of this study existed with respect to the cost of coal delivered to the household except for Murehwa where coal is delivered at about \$11/90 kg bag (1987 prices) and for the Mazowe Citrus Estates where coal is supplied free to the households. This section estimates the least possible cost of delivered coal to the households. These estimates are against the present coal pricing structure being used by coal merchants and by the Wankie Colliery Company.

Under our own estimates of the coal price build-up to the end-user (see Table 1) the estimated delivered prices for coal at each of the three districts per tonne are \$67.48 for Murehwa Ex. Dombwe, \$55.44 for Shurugwe Ex. Tongogara, and \$61.31 for Mberengwa Ex. Chingezi. These prices are based on the assumption that coal will be transported by rail to the nearest railway station of the surveyed area, and that road transport will be used from the railway station to the pricing point and that a 100% waiver of sales tax will be effected. Railage and road transport rate assumptions were 1.76c/tonne kilometre rail for Murehwa and 1.97c/tonne kilometre rail for Shurugwi and Mberengwa and 18c/tonne kilometre road for all places.

We also assumed a 15% dealer mark-up and bulk deliveries of coal to district centres as opposed to decanted sales.

Table 2
ESTIMATED DELIVERED COAL PRICES BY AREA OF DELIVERY
(\$/Tonne 1988) - ESTIMATED PRICE BUILD-UP

	Price Ex-Thompson	Railage to Nearest Yard	Road Transport	Dealer Price/Tonne	Delivered
MUREHWA	28	14.48	16.20	8.8	67.48
SHURUGWI	28	11.21	9.00	7.23	55.44
MBERENGWA	28	12.71	12.60	8.00	61.31

Assuming that a single household uses 90 kg of coal per month, the cost of coal per month to each household would be \$6.07 in Murehwa, \$4.99 in Shurugwi and \$5.52 in Chingezi, Mberengwa or \$72.84, \$59.88, and \$66.24 per year for each location respectively.

If the coal were to be delivered under the present coal merchant arrangements the prices would be much higher, at least \$10.10 per 90 kg bag for dry cobbles at Murehwa.

This estimate is based on Lakas' coal price build-up shown in Table 3. The price, even for Lakas, would be cheaper if a mechanism were in place to deliver coal in break bulk to a distribution point at the district.

Table 3
COAL PRICE BUILD-UP FOR LAKAS
(Dollars per tonne of dry cobbles 1988)

Price for Thompson Junction	25.00
Railage	18.53
Siding Charges	0.31
Delivered Price to Lakas Harare	43.84
Merchant's margin (invoiced)	3.07
Merchant's margin yard sales (26%)	12.20
Price collected FO Lorry in yard	59.11
Road transport (20 km)	6.00
Delivered to customer 20 km outside Harare	65.11

Source: Lakas

Other costs associated with the use of coal are, of course, the purchase of cooking stoves. Prices for some of the cooking stoves currently on the market are given below.

Table 4
PRICES FOR COOKING STOVES

All Metal No. 1 Stove	\$229.65
Master Cooker	\$375.72
Major Master Cooker	\$463.20
Wankie Stove	\$ 74.23

Source: Lakas, Wankie Colliery

The All Metal No. 1 stove has so far been more acceptable than the other stoves. Despite its price advantage, the Wankie Stove, which is a metal and brick combination, has not been very well accepted according to the experience of one distributor.

The use of coal also implies increased use of lighting fuels, kerosene or candles. This is because coal will not be able to provide lighting.

The annual cost per family of coal supply under the present distribution system would be at least \$121.20 for Murehwa. This cost could be reduced by about 40% if bulk sales were instituted and tax was waived. The household budget could be cushioned against seasonal strain if households could purchase coal into bulk storage during periods of high income. This would be a viable solution. It may have, however, the effect of placing severe strain on the household's income in that money would be tied up in coal stocks rather than being used for more urgent household requirements.

The success of the commercial coal option will also depend on the degree of budget flexibility the households may have: That means the level to which they can replace some of their current purchase items with coal purchases. The behaviour of the households in this regard is likely to be inelastic because their budgets are made up mostly of essential items.

Indeed, if energy becomes available only through the purchase of coal, households would have no choice but to pay for coal. This, of course, should not be misconstrued for financial flexibility on the part of the households but rather an act of desperation unless coal diffusion is accompanied by a compensatory improvement in the household income base.

ALTERNATIVE COAL MINING ARRANGEMENTS

At the beginning of the study we also thought that part of the high cost of coal could be attributed to the mining cost and profit margins enjoyed by Wankie Colliery Company as a coal mining monopoly in the country and that the cost of railage contributed even more significantly to the cost of delivered coal. These initial thoughts were examined in detail by a preliminary assessment of the possibility of reducing cost by producing coal from deposits nearest the areas of need and by using small-scale mining co-operatives rather than Anglo American. (See Maya and Zhou: "*The Technical Economics of Small-Scale Coal Production and Environmental Considerations of Domestic Coal Utilization*": ZIDS Working Paper, forthcoming).

The assessment concluded that:

- the capital outlays for small-scale coal mining would be too high to enable small-scale coal production unit costs to be lower than those at Wankie;
- that small-scale coal mining has high accident rates and would be exceptionally hazardous for cooperatives unless strict standards were stipulated by Government and close experienced supervision was made available to the miners;
- that the stripping ratios for most of the coal deposits closest to areas of severe wood shortage would be too high to be managed without high mechanization which in turn would be too costly under small-scale operations.

On the transportation costs, the study also found the existing option more favourable than the decentralized coal mining option. This is mostly because most of the areas which would require coal are not as close to coal deposits as was initially thought. Further, the area

between the end-user areas and the potential mines is not directly serviced by road or rail. Transport facilities would have to be developed to link up coal deposit areas with areas of coal demand. It would be most appropriate to link these areas by rail rather than by road as rail rates are lower than road rates. The capital costs of the railway option are, however, prohibitive and the road option is most likely to prevail. This would have the effect of pushing up the cost of delivered coal to households.

The small-scale coal mining option, thus, does not offer low prices for delivered coal to the households than the present option and could not be resorted to as an effective alternative.

ENVIRONMENTAL CONSIDERATIONS

Coal burning poses a hazard to health at four different levels: i.e. the resulting poorer lighting in the kitchen in cases where users cannot afford additional energy for lighting; carbon monoxide poisoning where effective plume dispersal and purging of combustion gases is not observed; sulphur dioxide exposure both in the household and in the village environment; and coal dust exposure as well as disposal in the environment.

On the first level, rural households, as is well known, use open fires for the multiple purposes of heating, cooking, and lighting. The design of the stove and the flameless glowing of coal inside the stove removes the lighting function of a household fire at night. This function would have to be served by additional energy from candles or kerosene at a cost.

Very often households fail for financial reasons to purchase the additional fuel in the form of kerosene or candles even in situations where fuelwood is free. The situation is bound to get worse when the basic household fuel is also to be purchased. Thus the households are likely to be subjected to poorer lighting conditions and as a result to suffer greater visual strain than under the free energy regime.

Carbon monoxide poisoning has occurred a number of times in the country. Such poisoning is a result of exposure to high concentrations of carbon monoxide gas due to the burning of coal in poorly ventilated houses and under bad coal combustion processes.

Carbon monoxide is odourless and colourless. If inhaled the gas dissolves into the blood system and replaces oxygen in the haemoglobin. With an affinity rate 200 times that of oxygen, carbon monoxide absorption into the haemoglobin is inherently faster than that of oxygen. This enables carbon monoxide to "suffocate" the victim internally and to poison him to death within hours depending on the density of carbon monoxide in the air.

The poisoning process does not choke the victim and proceeds without alerting him to the danger of the toxic environment as he lies asleep at night. Generally, however, the victim feels drowsy and sleepy with the initial dosage and falls continuously weak and sleepy as the dosage progresses to higher levels.

We assessed the possibility of such poisoning by analyzing the ventilation conditions of rural houses where coal would be burned. Particular consideration was given to houses where people slept in kitchens and in situations where coal would be used for heat generation at night or was likely to be left burning after cooking at night.

Window size and the use of kitchens as bedrooms at night were the variables used to measure the possibility of toxification if coal became a widespread fuel in rural households. Of the 799 households surveyed (with a total population of 5 593), 36% reported people sleeping in kitchens. In terms of individuals sleeping in the kitchen we estimated a total of

902 people or 16% of the population represented by the surveyed households. Of these, an estimated 77% slept in poorly ventilated kitchens. In some households up to 14 people slept in kitchens at night.

These figures give us the magnitude of the population likely to be directly exposed to toxic gases while sleeping. We also considered that people sleeping in bedrooms attached to kitchens faced harmful exposure albeit to a lesser extent. We thus surveyed households for such attachment of bedrooms to kitchens as well.

The 799 households surveyed had a total of 3 196 rooms in their households. Six hundred and seventy-one or 84% of the households had kitchens detached from the bedrooms. The rest, 16 percent, had kitchens attached to bedrooms.

From these figures we estimated that about 16% of the rural population in the surveyed areas, and by extension, of the total rural population, use kitchens as bedrooms and that 77% of these sleep in poorly ventilated kitchens and would thus be at high risk in terms of exposure to high concentrations of carbon monoxide — more so because as the survey showed, a large number of households, 50%, do not extinguish fire after cooking at night.

Sulphur dioxide exposure would be greater as well for the 77% sleeping in poorly ventilated kitchens than for the rest of the surveyed population. This would be the case with or without extinguishing fire at night.

The exposure to carbon monoxide for those who sleep in the kitchens will, however, be less severe unless fresh coal is added to the stove just before sleeping. This is because the emission of carbon monoxide occurs mostly during the pyrolysis stage of the combustion cycle for coal.

The progression of coal burning exhibits a long pyrolysis period and which increases with the difficulty of ignition and the restrictiveness of the burning chamber to airflow. In a kitchen coal fire the release of carbon monoxide increases every time the stove is restocked but to a lesser extent than during the initial ignition stage. In the use of coal for cooking the fuel would go through the pyrolysis stage and release all the toxic gases early before bedtime and most likely while the kitchen doors are still open and thus ventilation is still high and sufficient to purge the toxic gases emitted from coal.

This fact reduces the number of high-risk people for carbon monoxide exposure to those who restock their stoves just before retiring to bed or in the middle of the night to generate warmth during the cold winter months.

The number could be smaller than the 77% estimated earlier and it could be much greater because even people in the low-risk category may resort to the use of coal in the stoves or in "mbauras" for heat generation in the cold season. Thus, unless effective educational campaigns accompany the diffusion of coal, a real danger exists in terms of the exposure of large numbers of rural people to highly toxic pyrolysis gases from coal.

The study also estimated possible levels of household exposure to sulphur dioxide on the basis of the ventilation aspects of rural kitchens, the stove design, and on the sulphur content of input coal.

The coal likely to be used in rural households is the Wankie Bituminous coal with a sulphur content of 2.6% of mass on average. At this sulphur content level the concentration of sulphur dioxide is estimated at 3.7 PPM relative to the coal heat value. This concentration level is much higher than the concentration levels allowable at the international level. There are no local standards yet set in Zimbabwe.

It must be emphasised that all the possible internal exposure levels described above can only result if the stove design does not enable effective dispersal of gases. During the study we viewed a number of stoves in use and took particular consideration of the gas dispersal effects of the design. Basically the designs on the market have effective draught and pipes to remove the possibility of gas dispersal into the kitchen. This effectiveness, however, is subject to adequate cleaning of the flu pipes by the household and the effective control of downdraught. This can be done through pipe designs in relation to existing structures on or near the kitchen such that adjacent structures or rain do not force air back down the chimney.

In the Mazowe area where coal and coal stoves have been in use for a long time and in the rest of the areas surveyed, we did not receive any reports of toxification due to the use of coal in households.

Thus from the environmental point of view the major source of fear should be related to sulphur dioxide emissions into the outside environment and to the disposal of ash. However, the quantities burned in any village would be too small to cause any significant environmental damage. This is true for sulphur but not conclusive for coal ash which presents the risk of washing or draining heavy metals and other pollutants into the water and soil systems.

CONCLUSIONS

Generally literature on the diffusion of new technology is awash with reasons of cultural barriers and tradition as impediments to change. Results from this study indicate to the contrary. Although it may be true that change is slow or may be slow, reasons for this in the case of the diffusion of coal in the rural areas are not cultural or technological fixedness. Rather financial considerations, exposure, and availability of technology are much stronger determinants than culture and technological inertia.

We have found no serious attitude against the use of coal nor have we found any cultural considerations that militate against the adoption of coal or coal stoves among rural households.

Instead, there was a certain amount to enthusiasm on the idea of using coal.

The present incomes of most rural people would not be able, however, to support commercial energy and hardware. For this to be possible, programmes must be put in place to reduce the cost of coal and stoves to these households and concurrently to improve their income base.

The most feasible way to reduce the cost of coal is to supply coal in break bulk to centres in the user districts and to allow users to purchase coal on a continuous range of quantities such that the buyer decides what quantities they want to buy and that they can buy according to their ability at any given time.

It is also possible to reduce the cost of coal by removing or reducing sales tax on coal to selected groups or classes of rural households preferably those in the communal areas (as opposed to commercial farmers) in rural Zimbabwe. This subsidy by Government would go a long way in pushing the use of coal and in saving indigenous forests - a worthwhile counter-balancing benefit. The environmental effects of coal utilization in rural households can be minimized by educational campaigns and proper stove designs for effective combustion and dispersal of combustion gases.

The danger always exists, however, that some households may use coal as open fires or in hazardous devices. This danger can only be removed by educational campaigns and most effectively by policing or supervising the use of coal stoves, particularly the cleaning of chimneys and prohibiting restocking for overnight heating purposes.

All in all, the real major impediment to a successful diffusion of coal in rural households is the lack of institutional (Government) support to the idea, particularly in terms of tax concessions, effectively raising the income levels of rural people and devising an effective coal distribution mechanism. In this regard Government district offices and co-operatives could play a major role.