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SOUTH AFRICAN ENERGY CRISIS:

SOME SUGGESTED STRATEGIES

By

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SOUTH AFRICAN ENERGY CRISIS : SOME SUGGESTED STRATEGIES[1]

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ABSTRACT

Half of South Africa's population, living on farms and in underdeveloped rural areas, depend heavily on fuelwood and agricultural residues for meeting their basic energy requirements for cooking and heating. A further 17% of the population, who live in peri-urban areas and black townships and who also do not have access to the national electricity grid, also use fuelwood which currently amounts to about 14% of total nett energy consumption in South Africa.

A fast growing population, with restricted land access, is placing unsustainable demands on existing wood resources and severe environmental, social and economic consequences are inevitable unless investments are made in alternative energy sources for this sector. The demand for adequate access to convenient and cheap forms of energy will also rise with increased urbanisation in the years ahead.

Current substitution of fuels such as paraffin, coal and gas are resulting in households spending a disproportionately high level of their income on costly and inferior fuels to meet domestic energy requirements. Innovative energy packages involving electrification, the use of reconstituted solid fuels from wastes and decentralised renewable energy systems could ameliorate growing scarcities and hardships, provided that a political commitment is developed for the adoption of an appropriate energy policy and investment strategy for underdeveloped areas.

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INTRODUCTION

The focus of this paper is the underdeveloped sector in South Africa, which is defined here as being mainly the poorer black community which does not have access to electricity for domestic energy requirements. In 1984 this included about 3,3 million blacks in metropolitan areas, 1,5 million in other towns in South Africa, 4,5 million labourers and their families on commercial farms and nearly 12 million in the ten "homelands", totalling about two-thirds of South Africa`s population.

Energy consumption in underdeveloped areas is almost exclusively confined to household fuel use, the human energy required for fuelwood and water collection and also agriculture related activities. Development imperatives further require that adequate energy supplies be made available for community social welfare needs such as schools and clinics, and for production activities including agriculture and rural industries. Energy is also required for transportation. The latter area has best been dealt with elsewhere. This paper will examine current and future energy demand patterns and will outline appropriate strategies and technologies to meet these demands.

DOMESTIC ENERGY CONSUMPTION IN UNDERDEVELOPED AREAS

The proportion of households in underdeveloped areas using various fuels is summarised below:

TABLE 1 : Percentage households using different fuels

	Elec.	Wood	Wastes	Paraffin	Candles	Coal	Gas	Batteries
Rural homeland	<1	99	80	96	73	12	5	55
Farm Labourers	14	97	30	19	86	5	9	?
Peri-Urban	3	68	22	84	79	53	7	60
Townships*	29	38	2	71	77	47	14	?

Source: Eberhard (1985a) & *Moller (1985).

Energy consumption in 1984 in "homeland" villages and peri-urban areas in South Africa has been found to be:

TABLE 2 : Mean annual per capita domestic consumption

	Fuelwood Kg	Dung Kg	Paraffin l	Candles No	Coal Kg	Gas Kg	Total GJ
Villages	604	118	23	27	20	0,66	13,8
Peri-urban	334	-	46	51	156	1,90	12,0

Source: Eberhard (1985a)

Total domestic energy consumption in the underdeveloped sector was found to be 274,8 PJ, which was approximately 14% of total nett energy consumption in South Africa in 1984. Wood is the dominant fuel, and accounts for 80% of energy used in underdeveloped areas. This amounts to 12,88 million tonnes (air dried), which is equivalent to 219 PJ or 6% of total primary energy consumption in the country in 1984 (Eberhard, 1985a).

The significance of energy consumption in underdeveloped areas is further emphasized by the fact that 22 million of South Africa`s (including the TVBC areas) total population of about 31,4 million in 1984, do not have access to electricity and use wood (and also paraffin, coal and gas) to meet their basic energy requirements. In the year 2000, the total population is expected to increase to 45 million, of which about 35 million will be black, settled in the following patterns:

TABLE 3 : Distribution of South African black population (millions)

					Homeland				
		Metro	Urban	Rural	Urban	Fringe	Rural	Total	%Urban
1980	Population	3,96	1,71	4,35	1,49	1,45	7,78	20,74	34,5
	Share %	19,1	8,2	21,0	7,2	7,0	37,5	100,1	
2000	Population	8,9	2,86	5,72	4,03	3,92	9,34	34,77	45,4
	Share %	25,6	8,2	16,5	11,6	11,3	26,9	100,0	

Source: Simkins (1985)

It is apparent that the rural population will increase marginally, but that populations in urban and peri-urban areas will more than double. One of the phenomena associated with increased urbanisation is the growth of informal settlements in peri-urban areas around metropolitan centres and in closer settlements within the "homelands" where people have settled or have been settled at or close to urban densities, but with more rudimentary facilities, and seldom with access to electricity. This sector cannot then be ignored in national energy planning and investment decisions. The urgency of developing an appropriate energy supply strategy for underdeveloped areas is further underlined by appreciating that the most severe energy scarcities and problems occur in this sector.

ENERGY PROBLEMS IN UNDERDEVELOPED AREAS

Energy for cooking and heating

The primary energy requirement in underdeveloped areas is household energy for cooking and heating. Dependence on fuelwood for meeting these needs has led to a number of severe social, economic, health and environmental problems (Best, 1979; Gandar, 1984; Eberhard, 1985a):

* The social costs of dependence on fuelwood are high. The average woman spends most of the working day labouring over the provision of basic services which are simply taken for granted in most urban areas. Fuelwood and water collection trips are arduous and time consuming and are seen to be one of the key problem areas where alternative solutions would be welcomed.

* Dependence on fuelwood by growing populations has led to enormous and severe scarcities of available fuel from natural woodland. As a consequence there has been a significant shift in many areas to a new reliance on purchased wood from plantations. Problems of having to walk long distances to collect headloads are often replaced with the problem and cost of securing suitable transport to fetch wood loads. The actual price of wood, mostly from State woodlots, is still relatively cheap, but because of the cost of transport (typically 80% of the price of a delivered load), wood has become the single largest component of expenditure on fuel. Paraffin is also a large cost item and where wood is not available from either natural woodland or plantations, coal is becoming a significant fuel, most commonly in peri-urban areas, but also in some rural areas, particularly those near railway stations.

The mean amounts spent annually on fuel in the various areas studied by the author are:

TABLE 4 : Mean Annual Household Fuel Expenditure (1984/5 Rand)

	Fuelwood	Paraffin	Candles	Coal	Gas	Batteries	TOTAL
Villages	88	67	21	15	6	?	197
Peri-Urban	118	128	31	90	11	25	403

Source: Eberhard (1985a)

The continued reliance on wood, even in peri-urban areas, would indicate that for the foreseeable future there will still be a massive market for wood, even as the capacity of natural woodland to meet this demand diminishes.

One fuel which is still largely free and is now extensively used in rural areas, is agricultural residue, such as dung and mielie cobs and stalks. At present, its total contribution to domestic energy supply is still small, although it can be expected to increase as wood becomes scarcer, and will probably start becoming a commodity for sale. Most crop residues are currently used but only a small fraction of available dung is used for fuel, thus having minimal impact on soil fertility or environmental degradation.

* Of more serious environmental concern is the evidence of deforestation and denudation of woodland through the harvesting of growing trees for fuelwood. Although the evidence is mixed (and it appears that in at least some areas there has been a measure of control on indiscriminate cutting), the overwhelming evidence from most areas is that fuelwood is becoming scarcer and that demand for fuelwood is shifting the balance towards the destruction of tree cover.

Much more detailed ecological work needs to be undertaken in order to objectively document environmental damage consequent on fuelwood harvesting. This is important if we are to understand the long term and potentially irreversible environmental degradation and declining agricultural production which is likely, should there be no effort at securing alternative energy supply options for underdeveloped rural areas.

* There are also serious health and welfare costs related to the shortage and expense of domestic energy. Many households are perilously close to the minimum fuel required to meet basic needs and some are below this level. Cooked meals are skipped, extra foods or meat cannot be cooked with the staple mielie meal because they require more fuel; hot water cannot be heated to increase hygiene; and water collected from contaminated sources cannot be boiled before drinking.

* Wood scarcities have meant that more and more households are having to switch to alternative fuels, particularly in peri-urban and urban areas. With many of these households denied access to electricity, they are forced to use inferior and expensive fossil fuels. There is high degree of dissatisfaction with these fuels. A majority consider paraffin, gas, coal, and batteries to be too expensive and gas and candles to constitute a fire danger. Many complained that paraffin and candles are messy to use, that they provide poor light, and that smoke from coal and wood fires permeate clothes.

Water collection

After fuel for cooking, heating and lighting, adequate water supply is the most frequently stated problem in underdeveloped areas. The supply of water invariably requires energy to lift it to delivery points and certainly a great deal of human energy is currently utilized in the collection of water.

The average per capita water consumption in rural areas is 15 litres per day (compared to 200-300 l/day in urban areas). Water collection trips take about an hour each, three times a day, with women and children walking on average about a kilometre per trip.

The majority of households in underdeveloped areas have an unsatisfactory water supply. Springs are often unprotected and contaminated or run dry in drought periods; handpumps, windmills and diesel engines break down and are poorly maintained; and the delivery of diesel fuel is both costly and erratic. There is thus much room for improved systems of water delivery.

Community energy requirements

There is almost a complete dearth of adequate energy supply for communal services such as schools and clinics or for rural industry. The electricity grid has bypassed underdeveloped areas and diesel generators supply electricity to a handful of small towns, hospitals, mission stations and police and border posts. Again this supply is unsatisfactory and unreliable. Adequate skilled maintenance personnel are not available and the cost of diesel fuel has increased enormously.

There is thus a great need for reliable, low-cost, decentralised, small power supply systems to help improve the quality of essential services in rural areas and also to make possible the development of small scale rural industries.

ENERGY CONSUMPTION VERSUS DEMAND AND REQUIREMENT

In approaching the need for appropriate energy supply strategies for underdeveloped areas we have begun by summarising very briefly existing energy consumption patterns and problems. An appropriate energy supply strategy must, however, not only relate to existing consumption patterns, which may be woefully limited, but also to the quantities and type of energy required to enable improvements in social welfare and economic development. Another important factor to be taken into account is the energy demand expressed by communities in this sector. Energy supply, particularly in the form of grid electrification, has become a vocal public, and often political, issue in urban and peri-urban areas which see, but do not yet experience, the potential benefits of a clean, reliable and possibly cheaper form of domestic energy.

As Gandar (1984) points out, energy consumption, demand and requirement are frequently, but confusingly, used synonymously. They are, however, three quite different and distinct entities. Consumption refers to current usage patterns. Demand is related to subjectively expressed needs and will generally be higher than consumption, especially if energy is scarce or expensive. Energy requirement need not bear any relationship to either consumption or demand. It could be lower than both if there is scope for using energy more efficiently, or there may be no demand or current consumption of particular energy sources even though it is required (e.g. refrigeration for vaccines). Energy requirement refers to objectively assessed needs, usually according to some commonly agreed development objectives.

Clearly, there will be some debate as what constitutes reasonable requirement. The stance taken here, is that minimum energy requirements for underdeveloped areas should at least meet basic human needs. This implies adequate fuel for food cultivation and preparation (cooking), for heating and lighting, water delivery (and treatment), and for the creation of infrastructure to supply essential services. Energy should also be provided for the development of production, including improvements to agriculture and rural industry.

AN APPROPRIATE ENERGY SUPPLY STRATEGY

When considering the options for meeting the most pressing and basic energy requirements of underdeveloped areas, viz. domestic energy needs for cooking, space and water heating and lighting, one has to distinguish between rural areas with their current dependence mainly on wood, and peri-urban areas which are increasingly dependent on fossil fuels. In both sectors, current energy supply is unsatisfactory, but possible solutions will differ. This is because settlement patterns, distance from the national grid, predicted load factors, and disposable income will determine whether it is economically feasible or desirable to consider providing the standard option of the developed sector, viz. electrification through the extension of the national grid, or whether more decentralised systems based on renewable energy sources should be considered.

URBAN AND PERI-URBAN DOMESTIC ENERGY

An almost totally neglected area in energy research, planning and investments are the closer settlements, the peri-urban sector and the townships around the metropolitan centres. With little access to either agricultural land or natural woodland, the opportunities for the collection of "free" fuels are minimal; neither do these households have access to inexpensive electricity. Sandwiched between metropolitan and rural areas, this sector experiences energy problems quite different to either. Although still reliant on wood, which is mostly purchased from vendors, households are heavily dependent on the most costly, and perhaps least efficient of cooking, heating and lighting fuels.

Grid electrification

Electricity is undoubtedly the most versatile and convenient energy source, yet its use by South African households has largely been restricted to the developed urban areas and towns, and a high proportion of (white) commercial farms, while most of the black residential areas around metropolitan centres have been denied its benefits. Ironically South Africa produces nearly 60% of total electricity supplies in the entire continent of Africa.

The provision of electricity has become a major and exceedingly costly task in Third World countries. The World Bank, which lends more money for energy projects than any other institution, estimates that $ 130 billion (1982 $) is required per year over the next decade to meet the energy demands of developing countries. Almost half of this, $ 60 billion, will be needed for the development of electric power sources. In practice, the Bank lent $ 3,4 billion for energy projects in 1982 - 25% of its total lendings. South Africa is thus not alone in facing enormous demands for electrification. It is also encouraging that there have been instances where the political will to tackle electrification projects has been demonstrated, such as the recent electrification of more than 100 000 houses in Soweto.

There are a number of reasons why electrification of urban and peri-urban areas is the preferred energy supply option for domestic needs:

1) Once the initial extension fee has been paid, electricity is in most cases cheaper than other fuels for cooking, heating and lighting.

   In a survey by Rivett-Carnac in July 1979 in Umlazi it was determined that households without electricity spent on average R42 a month on fuel, while typical middle income households with electricity spent on average R 18 a month, using more energy in a safer and more convenient form.

   A survey by the author in September 1983 in suburbs around Cape Town revealed that families without electricity could pay up to three times as much on domestic energy than those families which had access to electricity (Eberhard, 1984b).

   This data clearly dispels the popular myth that most black households cannot afford electricity: the truth is that they can no longer afford not to have electricity.

2) Electrification can substitute for coal and wood usage in urban areas and thus has the potential to substantially reduce the severe air pollution in areas such as the Witwatersrand. More than half a million tonnes of coal are used in Soweto each year. South African coal has a high ash content and it is estimated that approximately 10 000 tonnes of ash is released per annum into the atmosphere over Soweto.

3) Electricity may also allow the performance of entirely new tasks, eg. the use of television, or washing machines. It is difficult to compare the costs of electricity with those of other sources for households, because in many cases the energy service supplied by electricity is of so much higher quality (lighting), convenient (ironing), or unavailable with other energy sources (TV), that the service is essentially a new and different one.

The benefits of grid electrification are not automatic, however, and many electrification schemes in Third World countries have revealed a number of unforeseen problems. Thought should be given as to how the financing of electrification could be structured so as not to unfairly burden the initial consumers. One strategy, in new housing projects, is to build in the cost of reticulation into the lease or purchase cost of the house, so spreading the capital cost of electrification over the longer period of repayment of the mortgage by the householder. Innovative financing schemes could also be developed to ease the initial costs of purchasing a range of electrical appliances.

For electrification to be successful, it should be coupled with an integrated package of energy conservation measures, including better house insulation, solar water heating, and awareness programmes of ways to use electricity efficiently in the home.

Unfortunately, it seems that the provision of services such as electricity is still regarded as being of secondary importance in the planning of townships and the upgrading of peri-urban and informal settlements. The massive housing project at Khayelitsha in the Cape is another example of where the electrification of houses has been ignored. There is no doubt that by denying electricity to these areas, communities are further impoverished, by having to meet the higher costs of fuels such as coal, gas, paraffin, candles, and batteries, and quality of life expectations are frustrated by being denied the opportunities and benefits of electrification. This situation can only exacerbate an already deteriorating social and political climate in these areas.

If all housing in and around the metropolitan areas and towns were to be electrified, an additional 5,5 million people would require less than 8000 million kWh per annum or 7% of the total electricity sent out by ESCOM in 1984. This would require little more than one third of the capacity of one of the new 3600 MW power stations currently being constructed.

Meeting minimal electricity needs with photovoltaics

There is no doubt that grid electrification is a costly and capital intensive option. The costs of electricity are also likely to rise with increased coal prices, the use of nuclear power, and restrictions on foreign loans. If full electrification is in some cases too expensive and costly a strategy, then the provision of minimal electricity requirements for lighting, television and radio/hifi sets might be economically and appropriately met with decentralised stand alone power supply systems such as photovoltaics.

Batteries are almost universally used throughout the underdeveloped domestic sector, mainly for radios and torches, although also lighting, hifi or television sets. Car batteries are often used and have to be recharged at short intervals mostly at the local motor garage or battery centre. A not insignificant number of households have instead begun to use small petrol generators to charge batteries and such cases were encountered by the author even in informal settlements such as Crossroads near Cape Town. In this situation photovoltaic systems become directly competitive.

There are successful precedents for such applications of photovoltaics. One of the more fascinating cases reported is that of the spontaneous growth of the Spanish photovoltaic market, which if one excludes the USA and demonstration projects, is the next largest in the world. Although the electricity grid is quite extensive in Spain it has in many cases become more economical to install PV systems which meet minimal electrical requirements. Some 24 000 houses in the Andalucia region and Baleares Islands have PV installations, typically in the 30 - 100 Wp range to supply electricity mainly for lighting, television sets and radios (Lorenzo, 1985).

The costs of photovoltaics in South Africa have unfortunately doubled over the past year from R 10 per Wp to about R 20 per Wp, because of the falling rand exchange rate. This is in contrast to international trends where costs of photovoltaics continue to fall.

Photovoltaics may be an intermediate solution to electricity demand in underdeveloped areas, but they also have the potential for being a long term solution to fully meeting household electricity demand. Photovoltaics remain the most elegant and innovative of all the electricity producing technologies: no working parts, and no high temperature working fluids mean production is possible. The constraint, however, as with all solar energy technologies is the extremely low density of the solar resource and thus collection areas have to be large, with resultant high equipment costs. There have been, and continue to be, rapid developments in photovoltaic technology which aim at minimising material requirements and increasing efficiencies in order to reduce costs.

Solar water heaters

Another energy source which can make an important contribution to alleviating energy scarcities and improving the quality of life in underdeveloped urban and peri-urban areas, is low-cost solar water heating.

Studies have indicated that the use of integral solar water heaters as an only form of heating water, is a viable proposition provided that the higher initial cost can be reduced by economies of scale and by collective financing under reasonable terms and conditions (Basson et al, 1984).

Energy efficient housing

After cooking and the provision of hot water, space heating constitutes the next most important domestic energy requirement in peri-urban areas. Energy considerations have seldom been taken into account in the planning and design of low cost mass housing. Houses have been poorly orientated, and the choice of building materials, lack of ceilings, interior doors or any insulation has meant that most structures are energy inefficient; i.e they experience high heat losses and therefore require high heating (or cooling) loads to maintain comfort levels. The consequence is that most peri-urban households spend a disproportionate percentage of their income on energy purchases - typically about 20%, compared to less than three percent for most middle income housing (Eberhard 1984b).

The question of providing energy efficient low cost mass housing which minimizes space heating requirements will become an increasingly important issue in the future as the rate of urbanisation accelerates. After job creation, perhaps the next greatest challenge facing South African planners is the provision of adequate and sensitively planned mass housing with affordable services. Energy is a dimension which should not be left out in the planning and implementation of these projects.

The creation of energy efficient building requires a greater appreciation of the way climate, orientation, design and building materials can be used to increase comfort levels. Orientating buildings to face north, maximising window glazing on the north aspect and minimising it on the south, and designing roof overhangs so as to exclude high summer sun, but which allow low winter sun penetration, are all commonsense features which can be incorporated into building design and construction with no added cost, but which will greatly increase comfort levels.

Further improvements can be made by incorporating insulation in the ceiling, walls and foundation, double-skinned walls, double glazing, increasing the thermal mass of floors and surfaces exposed to solar penetration and through special solar features such as Trombe walls. All of these will increase the cost of the structure and their advantages have to be weighed against potential energy savings.

It is probabl[illegible] to say that passive solar heating, including solar water heating and energy efficient building design, remain the most practical and cost-effective application for solar energy.

Reconstituted solid fuels

For peri-urban areas and closer settlements which are not on the periphery of metropolitan areas and are further away from the national electricity grid, one of the major domestic energy problems remains an affordable, convenient fuel for cooking. Wood is not freely available and the alternatives of paraffin, coal and gas are generally expensive or their supply unreliable.

One alternative which is beginning to be explored is reconstituted solid fuels from waste material. There are large resources of unused coal discards, wood and paper wastes which can be briquetted or pelletised into a convenient low cost cooking and heating fuel for underdeveloped areas.

There is a stockpile of approximately 200 million tonnes of discard coal which is growing at the rate of 20-30 million tonnes per annum. Discard coals consist of fines and high ash coals. There has been a tendency for beneficiation of coals to increase their export value and this has resulted in large dumps of tailings which are currently unused but which have a useful energy value.

There are also substantial amounts of unused wood wastes, mostly in the form of sawdust. It has been estimated by Sorfa (1983) that the sawdust residue surplus in 1985 would be more than 300 000 m^3 per annum. Competing uses for sawdust are the production of wood-cement composites, chipboard and paper production.

Reconstituted solid fuels are currently only marginally cheaper than coal, but the potential exists with large-scale production to produce a substantially cheaper fuel with good combustion characteristics, although some work still needs to be done on the pollution aspects of the fuel.

RURAL DOMESTIC ENERGY

It is unlikely, in the short to medium term, that grid supplied electricity will provide an appropriate energy source for meeting the household energy needs of underdeveloped rural areas. The costs of extending the grid to remote diffusely settled communities will be enormous. It is doubtful too, whether impoverished households, dependent in part on "free" wood resources will be able to afford the service unless the capital costs are heavily subsidised.

Electricity supply to rural households can, however, bring social benefits and hence indirect economic benefits; but it is questionable whether these alone could justify the costs of rural electrification. International experience in developing countries is of interest here. In the Phillipines, a large rural electrification scheme was embarked upon as a means for reducing support for communism (sic) and 60% of rural supplies have gone to the residential sector. The Chinese approach has stressed that there should be an established industrial demand, as a base load, in rural areas before promoting rural electrification, which would then also serve agricultural demand. The benefits of domestic electrification are viewed as subsequent.

Apart from the fact that household electricity consumption is not directly economically productive, there are other factors which add to the cost of supplying electricity for residential use in rural areas. Household demand tends to peak sharply at certain times of the day, giving rise to poor load factors, and thus raising the cost of supply, unless there are other balancing loads. Also, levels of household electricity consumption are usually very low (typically about a quarter of urban levels) and this leads to a higher unit cost of supply.

These arguments, however, have not had much impact on the growth of rural electrification schemes for "white" commercial farms and it would appear that within the next decade, very few farms will remain unconnected to the national electricity grid. Political and social factors may thus override questions of economic cost-benefits.

The issue remains, however, whether extending the national grid to remote areas, including "white" farms, is the most cost-effective way of supplying electricity (as opposed to decentralised renewable energy systems) and whether electricity is the most sensible or affordable means for providing energy for cooking and heating in remote areas.

Strategies to mitigate energy scarcities in underdeveloped areas must in the meantime focus around current demand by increasing fuelwood supplies and ensuring that they are used more efficiently. Afforestation programmes and the development and introduction of efficient wood burning stoves will thus be key elements in any programme. In the medium to long term, alternative energy sources will begin to supply an increasing proportion of these needs. These three options for supplying the domestic energy requirements of rural households will be examined below.

Afforestation

The primary focus of energy supply strategies for underdeveloped rural areas has to be on increasing the supplies of fuelwood in order to arrest and reverse environmental degradation, as well as to mitigate current social and economic costs associated with the collection of wood.

It has been estimated that current fuelwood consumption in homeland areas totals about 7 million tonnes (air dried), a further 3,6 million tonnes are consumed, mainly on commercial farms, and about 2,3 million tonnes are consumed in towns and urban areas. If it is assumed that the latter demand will increasingly be met from sources other than wood, then the major requirement for fuelwood will continue to be in rural areas. If it is further assumed that about half of current rural consumption can be met from natural woodland and forest on a sustained yield basis, then the woodlot requirement is currently about 5,3 million tonnes (air dried) wood. It has been estimated that current fuelwood sales from commercial plantations in South Africa total 236 500 tonnes (Directorate of Forestry, 1983). If we add estimated fuelwood sales of about 182 000 tonnes from "homeland" woodlots, then national fuelwood production is about 420 000 tonnes, way below the requirement of 5,3 million tonnes. The area required to produce this, assuming a yield of 7 tonnes per ha per annum, is nearly 750 000 ha - clearly a huge task when it is recognised that the total area under commercial plantations in South Africa is 1,2 million ha. and that the total area in the homelands is currently under woodlots is only about 26 000 ha.

The potential for large scale afforestation is limited by the lack of suitable land within "homelands" and competing demands by commercial forestry. It is forecast that South Africa will soon experience a timber shortage. The forestry guide plan for South Africa identifies about 28 priority areas and 954 500 ha of good land without restrictions and which could be used for afforestation. Of this, about 180 000 ha are in the "homelands" and this is the only area where plantations could reasonably be dedicated to fuelwood production, rather than commercial forestry.

If the task facing South Africa appears to be daunting then it is instructive to see what has been achieved elsewhere. The Republic of Korea provides an example of a nationwide tree growing programme which achieved dramatic results. In 1962, the promotion of reforestation, on a communal basis, was adopted as a major national priority because of the acute wood scarcities and serious environmental consequences. After substantial progress over the next decade, a ten year National Forest Plan was launched in 1973 with a series of ambitious targets, including the planting of one million hectare of trees. Intensive efforts were made to mobilise village level support and collaboration. By 1977, the basic targets of the Plan had been reached, five years ahead of schedule (Foley & Barnard, 1984).

A number of approaches to afforestation could be adopted. State or public woodlots, which has been the common approach in Southern Africa, could be established in those areas in which the community wished the State to assume this responsibility, and large, "efficiently managed" woodlots would ensure rapid afforestation. At the same time a large number of community woodlots could be initiated in those areas where democratically organised communities were determined to exercise control over new woodlots. The potential of voluntary and non-governmental organisations in this context is something which should not be ignored. Often they can provide a much needed bridge between local communities and authorities promoting tree growing programmes. This is particularly the case when it comes to ensuring that the interests of women, and the poor and landless are taken into account.

And then in order to ensure the widest possible spread of tree planting activity a number of nursery and demonstration sites could promote the concept of agro-forestry. Village surveys by the author have indicated factors other than fuelwood supply are considered important in the planting of trees; viz. shelter, fruit, and building material supply. It would thus seem to make sense to promote the planting of trees which have multiple uses and benefits. In this regard Leucaena leucocephala, the "wonder tree" from Central America, looks very attractive. It has been planted successfully in trial plots by the ARDRI Forest Farming project at Fort Hare in the Ciskei. For agro-forestry, Leucaena is best planted in hedges or rows along roadsides or in fields with intermediate areas cropped for maize, grains, root crops etc., but it can also be planted in dense stands for pole production and direct grazing, or in mixed woodlots with gum trees.

Charcoal production and use

It is probably unrealistic to expect that fuelwood demand can be met entirely from within "homeland" areas which constitute just 13 % of the total area of South Africa but accommodate the majority of its population. Some wood is already being trucked in from outside areas and it is likely that this phenomenon will continue.

The immediate problem here is that wood is probably the least transportable of all fuels because of its low bulk and energy density which makes transportation extremely costly. One alternative is to convert wood into charcoal which has a very much higher energy density than wood and is therefore more economical to transport. This is the solution which has been adopted in many East African countries where the production and transport of charcoal, particularly to urban or peri-urban areas, are widespread, although it is almost unknown in Africa south of the Zambezi River.

The production of charcoal, however, is very wasteful of wood resources. Depending on the technology employed, between 4 and 8 tonnes of wood are required to produce one tonne of charcoal. Charcoal production only makes sense, then, if the end user is some distance from the source of wood (Eberhard, 1985b).

Apart from existing roundwood resources and wattle forests, a further source of raw material for charcoal production is wood residues. The estimated total residue surplus in 1985 has been forecast at 1,87 million m^3, most of which derive from tops and branches (Sorfa, 1983).

A further source for charcoal production is encroachment bush. There are now two small local firms in the Western Cape which utilise Acacia cyclops and Acacia saligna from contracts to clear farming land, and potential exists in many other areas of the country where encroachment bush has become a

Finally, the possibility exists for the establishment of energy plantations dedicated to the production of charcoal for underdeveloped areas. This would have to be a policy decision motivated by welfare and environmental protectionist motives, as the industrial and export markets are likely to continue to be more more attractive.

The use of charcoal for domestic cooking purposes by a culture unfamiliar with the fuel and its characteristics requires careful formulation of extension and dissemination strategies coupled with the introduction of fuel-efficient wood and charcoal burning stoves. The use of simple charcoal burning stoves is quite widespread in countries such as Zambia, where 90% of the population rely on charcoal for cooking and heating purposes. Wood and coal burning stoves are fairly uncommon in underdeveloped areas in Southern Africa, however, except in closer settlements and peri-urban areas. It is in these areas that charcoal could first be distributed, and there is the added advantage of it being a smokeless fuel. Current stoves have not been designed for optimum combustion of charcoal and programmes aimed at introducing simple low-cost fuel-efficient wood-burning stoves should incorporate the possibility of the introduction of charcoal as an alternative fuel.

Fuelwood demand mitigation through fuel efficient stoves

Another way of increasing the availability of wood is to use it more efficiently. The amount of heat contained in wood which is transferred to the cooking pot over an open fire, can be as low as 3%, although if the fire is sheltered from wind and increased convective losses, efficiencies can be as high as 15-20%. The use of low-cost fuel efficient stoves has the potential to double these efficiencies and thus halve the demand for fuelwood.

Much effort has been devoted to the development and dissemination of low-cost fuel-efficient wood burning stoves, and the ability of improved stoves to slow deforestation, erosion, and desertification, and to improve the lives and living conditions of half the world's population has approached almost mythical proportions. Yet despite years of effort, the potential of improved stoves remains unrealised.

Experience has now shown that enthusiasts, many of them working on short term aid contracts, have mostly produced badly designed stoves which have often used more fuel than a well shielded "three stone" fire.

particularly true of the heavy mass mud/clay Lorena type stoves. Apparently low-cost because they can be built from local materials and by the users themselves they have proved to have a life span of a couple of months to two years before severe degradation makes them inoperable. More serious has been their sensitivity to quality control. If potholes and flue gas passages are positioned incorrectly poor cooking efficiencies can result. There is thus a large hidden cost in the dissemination effort which requires trained and skilled stove builders. It can also be shown that for short cooking operations heavy mass stove walls can actually absorb more heat than bare lightweight metal walls lose to the outside. The poor record of stoves programmes can in many instances be attributed thus, not to "cultural factors", but simply to the fact that the stoves did not work very well.

More success has been obtained either through modest improvements to traditional stoves, such as the ceramic types in Asia, or to the development of light weight metal stoves combined with a low cost insulation material. This is the route which has been followed by the Energy Research Institute of the University of Cape Town. Exfoliated vermiculite is a low cost readily available insulating material in South Africa and combined with a refractory cement can be bonded onto thin gauge galvanised sheet metal. Working from first principles, and from needs identified in village level surveys, we have designed single and multi-pot stoves which have achieved in excess of 50% efficiency under laboratory conditions. These stoves are now being field tested and modified according to users' responses. The interaction of university laboratory and rural development programme has been critically important in this project and provides an example of the unique potential in the South African context of focussing skilled technical resources on immediate and proximate problems of underdevelopment.

It has been our experience that households, particularly those in closer settlements, are buying currently available coal/wood burning stoves which look modern but which cost up to R 1000 and are wasteful of fuel. The development and marketing of a low cost, well made and packaged, fuel-efficient stove can make an immediate impact on fuel, and hence financial, savings in many households in the underdeveloped sector.

Biogas

The generation of biogas by anaerobic digestion from organic waste materials, including mostly agricultural wastes, has been relatively successful in both India and China where approximately 8 million digestors have been built, although not all of them are still in use. Biogas, which comprises mostly methane, is ideal for cooking and if successfully implemented could significantly ameliorate the effects of fuelwood collection from receding woodlands.

Biogas digestors have not been used widely in Africa, despite a number of dissemination efforts in countries such as Tanzania, Zimbabwe, Lesotho and Botswana. Their use has been restricted to a handful which have been built by enthusiastic expatriate aid personnel.

There are just over 4 million head of cattle in the "homeland" areas in South Africa and the maximum theoretical biogas yield from their dung is only of the order of 17 PJ which is approximately a sixth of total household energy use in these areas. In practice only a fraction of this dung could be collected and so biogas from cattle dung could at best make a tiny contribution to energy supply in this sector.

Solar cookers

The use of solar energy for cooking would appear at first sight to be an attractive alternative to the combustion of fuelwood. The sun is an abundant resource in most developing areas and being diffusely distributed lends itself to small scale decentralised collection systems. A number of novel solar cookers and ovens have been built which work well and cook most types of food in a reasonable period over midday. The idea is not new and workable systems were designed in the nineteenth century for French troops in Africa. Renewed activity followed in the 1970`s after the two oil shocks, but like fuel-efficient wood stoves there are few reported success stories.

Within Southern Africa there have been two significant efforts at developing and disseminating solar cookers; one in Lesotho and the other in Kwazulu. In both cases about 40 cookers were distributed at little or no cost, but after an extended monitoring time there appeared to be no significant use or adoption of the devices and little discernible fuel savings (Eberhard, 1983; Thomas, 1984).

Problems about the diffusion of this technology include the restriction to cooking at midday, constant need for tracking the sun, allowance for single pots only, the design and origination of the projects, no ancillary space heating benefits, loss of the social function of an open fire and potentially the high cost of the devices.

Cooking is probably the most culture-bound of all activities and a change in cooking practices is not easily achieved. Given the above drawbacks, it would seem that afforestation and the introduction of fuel-efficient wood burning stoves have far greater immediate chances of making an impact in ameliorating energy scarcities and the associated social, economic and environmental costs.

ENERGY FOR WATER PUMPING

The World Health Organisation has set as a reasonable goal for the current Water Supply Decade a minimum water consumption of 50 litres per capita per day. The long term aim, though, is to provide all people with ready access to safe water in the quantity desired.

The water needs for irrigation are more difficult to quantify. The quantity of water needed to irrigate a given land area depends on many site specific factors such as the nature of the crop, climatic conditions, type and condition of soil, land topography, field application efficiency and the water quality. It is not feasible, then, to generalise or set a "standard" amount for irrigation. When planning an improved water supply, assessment should be made "in situ" of the agricultural water requirements, or by comparison with similar areas having already improved water supplies.

Many villagers use unprotected surface sources, such as springs, rivers or dams, as their primary water source. These are often shared directly with animals and other activities, such as washing clothes. This type of source may be improved by capping springs or by erecting a fence around the water source to exclude activities likely to contaminate the water.

The next step in improving water supply could be the utilisation of an underground water source by digging a well or borehole. Groundwater sources have many advantages over surface sources: they can provide water of a fairly consistent quality, free of turbidity and pathogens and they are less susceptible to the effects of drought. Water drawn from deep wells or boreholes often needs no treatment before drinking. It is at this level of water supply that the use of appropriate energy technologies for water lifting becomes important. A reliable pump, coupled with storage tanks, can dramatically ease the burden of water collection, reduce the effects of drought and even allow for reticulated water supplies to houses or field irrigation systems.

Any assessment of water lifting technologies should take into account the physical, social and economic environment in which the technology is to operate. Because of the scarcity of capital and technical skills in rural areas, water pumps should be low cost, but robust, with minimal maintenance requirements.

The most commonly used technologies are handpumps and windmills, whose technology has changed relatively little over the last half century. The rural landscape is littered with pumps which have been poorly sited, badly maintained and are no longer operable. Recent innovations in Third World countries have produced much improved devices. Examples are the Blair pump from Zimbabwe and the RIIC windmill developed in Botswana which makes more efficient use of low wind speeds. Photovoltaic water pumping holds much promise as a reliable pumping technology for low-lift applications and the Energy Research Institute at the University of Cape Town is currently monitoring a demonstration project in Kwazulu in order to assess the appropriateness of this technology for similar applications.

There is much scope for a substantive national effort to improve rural water supplies by utilising more appropriate technologies, coupled with community involvement in order to ensure optimum use and care of systems.

PRODUCTION AND WELFARE ELECTRICAL REQUIREMENTS

It was argued above that rural electrification is desirable if used to support production and welfare objectives. However, we also pointed out that grid electrification is extremely capital intensive. Consequently, the extent of rural electrification in developing countries is extremely low: about 23% of the village/rural population in Latin America, 15% in Asia and less than 4% in sub-Saharan Africa.

Developing countries with higher per capita incomes generally consume more electricity per capita and also devote more investment resources to rural electrification than do poorer countries . Nevertheless no causal relationship between increased electricity usage and rural economic development has been established. The supply of electricity (or other forms of energy) is, at best, a necessary, but not sufficient, precondition for economic development.

Though household benefits of electrification may be of some importance, the more significant potential for economic development lies in its use in productive enterprises, in agriculture and industry. In agriculture, electricity may be used for large commercial agricultural enterprises, such as lighting for hatcheries, or fans for ventilation of poultry or broiler farms, or milking machines in dairies. There is likely to be little scope for this application in underdeveloped rural areas in Southern Africa because of current land use patterns with the emphasis on small farming systems, and the need to maximise labour opportunities. A second use for electricity is to power seasonally needed agro-processing equipment that can relieve bottlenecks at harvest time, such as threshers, hullers, or milling machines. Thirdly, electricity can be made available for the important use of irrigation. India is an interesting example in this respect, where the emphasis in rural electrification has shifted from households to irrigation tubewells, in the interest of increasing agricultural productivity. The percentage of electricity used for agriculture in some Indian states has been extremely high (e.g. 39% in Haryana). Four million pumpsets had been installed by the beginning of the Sixth Five Year Development Plan, with the goal to electrify an additional 2,5 million pumpsets. The impact of irrigation on a suitable area can be dramatic, with the value of output often increasing severalfold in a short period. There is also some evidence that the small farmer may benefit proportionately more than the large farmer from irrigation, primarily due to more intensive cultivation by small farmers.

Welfare objectives can also be aided by the introduction of electricity for social and public uses such as schools (lighting and audio/visual equipment), sterilisation, and refrigeration in health clinics. Electrification can also result in a number of indirect benefits in the form of environmental improvements, foreign exchange savings, lowering migration and fertility, political stability, and innovation.

The use of small, decentralised off-grid power systems using renewable resources is likely to prove more cost effective than grid electrification in rural areas. The potential of small hydro systems has not even begun to be realised and biomass, solar and wind generating technologies are maturing to the point of commercialisation.

CONCLUSION.

The energy crisis is not over, at least for the underdeveloped sector it is not. Growing fuelwood scarcities are resulting in severe social and environmental costs, and an increased economic burden on the poor who are paying more for less. The provision of household energy takes up a substantial part of the resources of poor households either in cash purchases or in the time and effort required to gather wood or agricultural residues. We have seen how women in rural areas spend most of their working day labouring in non-productive activity over the provision of basic services that are simply taken for granted in most urban areas.

And in those township and peri-urban areas which are denied electricity, residents are being further impoverished through their forced reliance on costly and inferior fuels. With increased urbanisation, the lack of adequate services is bound to exacerbate an already unstable political environment.

Until now, only trivial amounts have been invested in energy supply for underdeveloped areas, while it is clear that it is in this sector that the most serious shortages and problems occur. If problems of poverty and development in South Africa are to be tackled, then the question of energy provision cannot be ignored.

South Africa is in a unique situation with its skilled manpower resources and its highly developed economy existing alongside a large underdeveloped sector. The potential exists for South Africa to play a leading role in the research and development of technologies appropriate to developing areas.

There is no escaping the fact that large amounts of capital are required for the establishment of appropriate institutions and techniques to cope with the enormity of the task of providing electricity to millions of South Africa`s citizens, of halting the denudation of woodland cover, environmental degradation, and providing cheap, abundant supplies of fuelwood and alternative fuels necessary for the meeting of basic needs and the stimulation of productive enterprise. Ignoring these problems may, in the long term, incur even higher social, environmental and political costs.

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