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AND DEVELOPMENT IN SOUTHERN AFRICA

Energy, Poverty and Development in South Africa

by

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ENERGY, POVERTY AND DEVELOPMENT IN SOUTH AFRICA

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1 INTRODUCTION

The quantity and nature of energy used by human societies has always been closely related to their level of social and economic development. However, the relationship between energy use and development is complex and is still inadequately understood. Nevertheless, two broad generalisations can be made. Firstly, increased levels of economic activity, as measured by GNP per capita, are associated with higher levels of per capita energy consumption. Superimposed on this relationship is another: the higher the per capita energy consumption, the smaller the proportion coming from traditional renewable energy resources such as fuelwood and agricultural residues. These two relationships are shown in Figure 1 and Table 1.

1. For example, South Africa and Brazil have approximately the same GNP/capita, but South Africa consumes nearly three times as much energy per capita as Brazil. Likewise, South Africa consumes approximately the same amount of energy per capita as Spain but produces less than half its per capita GNP.

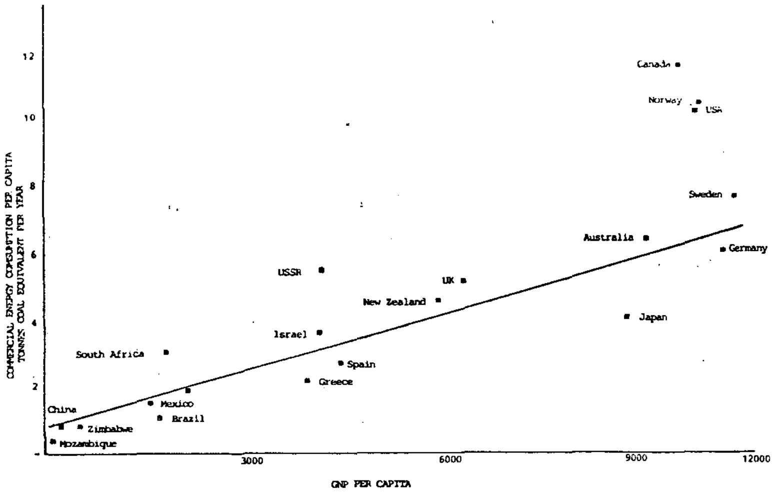

FIGURE 1: PER CAPITA ENERGY CONSUMPTION VS GNP PER CAPITA (1979)

Source: World Development Reports 1981, 1982

COUNTRY	GNP/CAPITA US $	PER CAPITA ENERGY GJ	% SHARE OF TRAD FUELS
Malawi	230	26,8	94,3
Mozambique	230	23,3	89,1
Tanzania	280	23,5	91,5
Lesotho	420	18	78,6
Angola	470	14,9	77,4
Zambia	560	26,1	58,3
Zimbabwe	630	33,0	52,0
Swaziland	680	42,8	60,0
Botswana	910	27,3	56,1
TOTAL SADCC	370	24,3	79
South Africa	2300	60,6	10

TABLE 1: NETT ENERGY CONSUMPTION IN SOUTHERN AFRICA IN 1980

Source: Eberhard, A A (1984a)

It will be noted that the relationships are neither precise nor are they entirely predictable and that many examples may be cited which contradict the general trend (1). Studies of individual countries also indicate that annual changes in energy consumption are not associated with equivalent or proportional changes in GNP (Darmstadter et al, 1977). There is little basis therefore for asserting a causative relationship between energy consumption and development. Energy use is only one element within wider social, economic and environmental factors. At best it is a necessary, but not sufficient, condition and a major driving force for economic growth and development.

As people have discovered ways of using and developing new energy forms, greater control has been able to be exercised over their environment and greater opportunities have been available to improve their material well being. The shift from muscle power to the combustion of fuelwood and then to the more energy intensive fossil fuels, such as coal, gas and petroleum, has determined the degree to which economic and productive activity has been able to expand. For example, the iron smelting industry in Britain in the early eighteenth century was in serious danger of collapse because of severe deforestation and the consequent lack of availability of large amounts of wood charcoal on which the industry depended. The subsequent exploitation of coal enabled iron smelting to survive and laid the basis for the industrial revolution. By the year 1900, 225 million tonnes of coal were being consumed in Britain. To have harvested the equivalent amount of energy in the form of timber would have required a forested area of about 600 000 km^2. The total area of Britain is only about a third of that (Foley, 1981: 57). Coal was superior to wood as an energy source and oil in its turn has a higher energy value and is a far more mobile form of energy than coal. A measure of the change which has occurred can be obtained by a simple comparison. One tonne of oil contains an amount of energy equivalent to the hourly output of 16 800 horses.

But development has seldom been even and an examination of the relationship between energy use and development leads to questions of equity and poverty. The rich industrial societies have tended to be extravagant in their use of energy, particularly during the period of abundant inexpensive oil, while the underdeveloped world has remained overwhelmingly dependent on depleting fuelwood resources, which remain the principle source of energy for cooking, space heating and other rural household needs for a large proportion of the world's population. The fuelwood needs of many areas in the Third World cannot be contracted and energy is required essentially for survival. The consequences of energy shortages are often vividly apparent in terms of human hardship and environmental degradation (2).

These issues of energy, poverty and development are strikingly evident in South Africa with the existence of a developed energy intensive industrial economy dependent on fossil fuels, supporting a minority population at a high standard of living; alongside an underdeveloped sector where the majority of the population live in poverty and are dependent on scarce fuelwood resources.

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2. Focus on these problems has often been at the expense of an examination of energy requirements for development. However, we should warn against dichotomizing rural energy into energy for subsistence and energy for development. The usefulness of such a framework is in conceptualizing and evaluating energy needs. Beyond this the dichotomy concept may be counterproductive since it takes, as its starting point, a traditional rural energy model in which the possibilities for truly effective innovation are severely limited. In fact all issues of survival are inseparable from the crisis of underdevelopment, and energy, as much as any other parameter, belongs in the development sphere.

Energy policy in South Africa has concentrated exclusively on commercial fuels such as coal, gas, petroleum and electricity for the industrial and metropolitan centres, and has ignored renewable energy resources such as fuelwood and agricultural residues and the needs of underdeveloped areas. These areas lack even a coherent development plan in which energy issues can be located.

2 ENERGY RESOURCES AND POLICY IN SOUTH AFRICA

Electricity is one of the most sophisticated and convenient forms of energy and it is steadily assuming a greater share of total energy supply. South Africa was one of the first countries to use electricity on a commercial basis, soon after the development of diamond and gold mining, and today the Electricity Supply Commission (Escom) ranks among the top seven electricity suppliers in the world. It produces approximately 60 per cent of Africa's electricity, yet the majority of South Africa's population is denied access to the electricity grid which serves mainly the "white" urban areas and some farms (3).

Electricity is produced almost entirely from coal, except for a very small amount which is produced from hydro-power and less than 10 per cent from nuclear power when Koeberg is fully commissioned. Figure 2 demonstrates the dominance of coal as a primary energy source in South Africa. Low labour wages have resulted in inexpensive coal which has supported the fast growing electricity supply and industrial sectors. South Africa has large coal reserves and the country will remain primarily dependent on this fuel

3. Escom produces 94% of South Africa's electricity and it is estimated that the share of electricity energy will rise from a current 23% to 40% of the country's total energy requirement by the end of the century.

well into the next century. Coal is also being converted to petrol to help satisfy the demand for liquid fuels and to reduce the importation of petroleum, which currently contributes a fifth of South Africa's primary energy consumption.

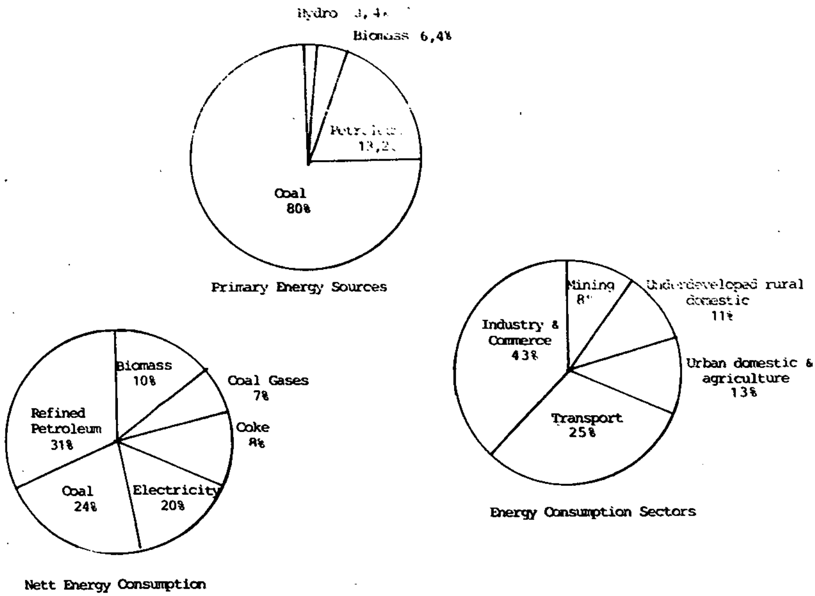

FIGURE 2: ENERGY CONSUMPTION IN SOUTH AFRICA 1982

Biomass, mainly in the form of fuelwood, contributes a relatively small amount to the country's primary energy supply. This fuel is used mainly by the underdeveloped rural sector in which the majority of South Africans live. No official figures are available for energy consumption in these areas which have been ignored in government energy planning and forecasting. We estimate that an average of 12 GJ per capita is consumed annually by the 15 600 000 Africans living in the homelands (including Bophuthatswana, Ciskei, Transkei and Venda) and in "white" rural areas. This results in a total nett energy consumption of nearly 190 PJ which is about a tenth of total nett energy consumption in South Africa, (4).

The population in underdeveloped rural areas are forced to rely on scarce fuelwood resources. Yet within South Africa as a whole, there is no desperate shortage of forestry resources. More than 1,2 million ha are currently under commercial plantation and large amounts of wood are wasted from the harvesting and milling processes without any energy recovery. It has been estimated that about 7 million tonnes of wood wastes are available annually, but very little of this is directed towards the fuel needs of the underdeveloped sector.

Growing populations restricted to underdeveloped homeland areas are exhausting the natural resource base and are being denied access to new forms of energy which would relieve pressures on the natural environment and allow positive development activity.

3 ENERGY RESEARCH IN UNDERDEVELOPED AREAS

Concern about declining reserves of timber and woodfuel in the Cape dates back to warnings expressed in the 1680's and culminating in a proclamation issued in 1704 which included: 'none of the inhabitants shall cut fuel other than by permit and at the appointed places, nor take more than permitted

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4. PJ = petajoules = 10^{15} joules
   GJ = gigajoules = 10^{9} joules
   MJ = megajoules = 10^{6} joules
   3,6 MJ = 1 kWh
   1 kWh is equivalent to the amount of energy consumed in one hour by a one bar electric heater or 10 standard 100 W light bulbs.

him' (Grut, 1977). Given that the problem is centuries old, it is surprising how little it has been studied.

The Social and Economic Planning Council (1946) estimated fuelwood consumption to be six tons per family per year in the Transkei. The first study of domestic fuel use in rural households was published by Best in 1979. Since then, fuelwood consumption by communities in Gazankulu and in Kwazulu have been studied by Liengme (1983) and Gandar (1982) respectively.

On the basis of somewhat inadequate data a few estimates of the total annual fuelwood consumption in South Africa have been made. The official estimate of 360 000 m^3 (Department of Forestry, 1975) cannot be taken seriously. Le Roux (1979) estimated 7,2 million m^3 for rural populations. On the basis of 1980 census figures Gandar (1983) estimated the annual consumption for the whole country (plus independent homelands) to be 7,3 million tonnes (oven dry) wood which is roughly equivalent to 12 million m^3.

Table 2 summarises the average per capita domestic energy consumption measured by researches in South Africa.

The differences in fuelwood consumption reported by various researchers may be explained chiefly in terms of the availability of fuelwood and to a lesser extent by climate. These variations clearly need to be taken into account when calculating total rural energy consumption in South Africa. Ideally, measurements of fuel use should be taken in a number of areas representative of different vegetation types, silvicultural potential, fuelwood availability and energy use patterns.

There has been very little research into other aspects of energy in underdeveloped rural areas in South Africa other

REFERENCE	AREA	FUELWOOD tonne	DUNG tonne	PARAFFIN ℓ	OVERALL GJ
Social and Economic Planning Council (1946)	Transkei	(0,960)	x	x	(16,32)
Best (1979)	Jozanna's Nek Transkei	0,271	0,080	10,24	7,69 (5,95)
Best (1979)	Mashunka Kwazulu	1,124	-	5,68	23,86 (19,32)
Gandar (1983)	Mahlaba-tini Kwazulu High grassland	0,62	(0,012)	< 2%	(10,68)
	Valley Lowveld	0,74	0,2%	< 2%	(12,58)
Liengme (1983)	Gazankulu Mopane veld	0,76	x	x	(12,92)

Notes:

1) Domestic energy consumption excludes human and animal energy inputs and is defined as the energy supplied by fuels for cooking food, for heating water for washing and for providing space heating and light.

2) Figures in brackets have been calculated and derived from data reported in papers, using the following average energy values for fuels given by Bialy (1982), Table 2.4: Charcoal 32 MJ/kg; wood - air dry (15% moisture d.b.) 17 MJ/kg; crop residues - air dry 16 MJ/kg; dung - sun dried (40% moisture d.b.) 12 MJ/kg; paraffin 37 MJ/ℓ .

3) Paraffin is included as the most commonly used commercial fuel, but in most cases its share of total household energy consumption is small - typically less than 2 per cent, and was thus ignored by Gandar and other workers.

TABLE 2: DOMESTIC RURAL ENERGY CONSUMPTION PER CAPITA PER YEAR IN SOUTH AFRICA

than some uncoordinated work on energy technologies for rural areas which has generally been far removed from rural realities (5).

4 ENERGY REQUIREMENTS FOR RURAL AREAS

4.1 THE DEFINITION OF REQUIREMENT

Energy consumption, demand and requirement are frequently confused with one another. They are, in fact, three distinct, different and sometimes unrelated quantities. Surveys generally measure consumption. Demand in many cases will be much higher than consumption, especially if energy is scarce and expensive. Requirements need not bear any relationship to either demand or consumption. It could be lower than both if there is scope for using energy more efficiently, or there may be no demand for energy even though it is required (e.g. for sterilizing drinking water). Energy requirements are difficult enough to define, let alone determine.

Reiterating the point raised in the Introduction, energy cannot be separated from developement. The energy requirement is a product of development policy which in turn is limited _inter alia_ by energy constraints. The energy requirements outlined below are the sort which would have to be met if there were to be small scale economic activity, improvements to agriculture, infrastructure, and the quality of life without large disruptive changes to lifestyles.

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5. See the proceedings of the conference 'Energy for Underdeveloped Areas', organised by the Energy Research Institute, 9 & 10 February 1984, at the University of Cape Town.

When it comes to the finer details of energy provision, regional or village scale energy packages must be designed since needs and resources may be very localized. Rural development often proceeds on a project by project basis which requires integrated energy packages. There is no universal package and the energy requirements of each situation have to be examined.

4.2 DOMESTIC

In this section we consider energy for cooking, space heating, lighting and for obtaining domestic water supplies, which are some of the basic necessities of life required by all households irrespective of wealth or poverty. What were generally free and abundant resources are now scarce and costly: costly in terms of the high proportion of the meagre household budget spent on various fuels, in terms of the opportunity cost of the time and human effort expended in gathering wood and fetching water, and costly in terms of the environmental degradation which accompanies over-exploitation of resources.

Because of the serious impact the scarcity of domestic energy has on rural households and because of the immediacy of the problems, a separate paper has been devoted to the subject (Gandar, 1984). In this section we will just touch on some of the main points.

4.2.1 NON-COMMERCIAL FUELS

By non-commercial fuels is meant those which are traditionally free such as wood, dung, leaves and crop residues. The term 'non-commercial' is a slight misnomer since firewood may become commercialized as shortages occur, but mostly as an informal sector activity which goes unrecorded.

As we have said, requirements are not the same as consumption and cannot be measured. There is a potential for reducing consumption by careful use of fuel, but the concept of requirement must be greater than the absolute minimum for survival and include a degree of comfort such as space heating in winter. A figure of three to four tonnes per year for a typical rural household of seven people seems a reasonable guideline. It might be greater in areas with a cold climate and less in areas where paraffin is used in limited amounts. This is an intuitive figure based on measurements of consumption given in Table 2.

The expenditure of time and effort on gathering firewood will be discussed in detail in another paper. Because of all the other demands on time there is little opportunity for increasing the time and effort spent gathering as wood becomes scarce, so the quantity used drops and the proportion of other fuel types increases. Of these, dried cattle dung is probably the most significant since it's use as fuel can disrupt the nutrient cycle. In a village in Lesotho, Best (1979) measured a rate of dung burning of 1,35 tonnes per family per year which is 33% of the energy budget of a household, but it is not used that intensively in South Africa. Although the burning of dung has caused alarm in some parts of the world (in India it is said that it causes nutrient losses equivalent to a third of the countries' fertilizer needs) the impact of this practice on soil fertility in South Africa is probably slight except in a few possible specific cases. Even in a Transkeian village of 200 families studied by Best (1979), the 100 tonnes of dung burnt per year by the whole population was only about 2% of the dung produced by their livestock.

Except in areas of dire shortage, other fuels such as dung, aloe leaves and maize cobs are usually used only for specific tasks, particularly those which require a cool smouldering fire like brewing and firing claypots. Dung is sometimes used in windy conditions since it does not flare up. These fuels only contribute a tiny proportion of the overall energy budget.

The use of specific fuels for specific tasks applies to firewood also. Certain species may be used for particular tasks provided wood is plentiful enough to allow such choices. Pieces of different cross-section are also used differentially for cooking quickly in the morning, slowly in the evening, heating water, kindling and space heating. It is analagous to the different settings on a stove and so the requirement is not simply for an absolute amount of wood but for pieces to fit particular tasks.

4.2.2 COMMERCIAL FUELS

While the extent to which dried dung and maize cobs are used as fuel is strongly correlated with wood shortages, the extent of paraffin usage does not show the same trend. The amount of paraffin used is more of a function of closeness to the modern sector: both in a geographical sense and also the amount of contact individuals have had with the modern sector. The average rate of consumption in various rural communities in South Africa seems to vary between two and six litres per household per month, but data are very scarce. As with other fuels, paraffin seems to have specific uses especially lighting, ironing, and quick cooking.

Electricity is widely used, though in energy terms its contribution is negligible. The main source is dry cell batteries used in torches and radios in particular. A very few homes are wired for 12 volt power provided by a lead plate battery, or have their own generators. Other forms of energy include wax (i.e. candles) which is used in a majority of homes though not necessarily regularly.

Coal, charcoal and gas are very rarely used in rural areas.

Commercial fuels are used extensively in underdeveloped peri-urban areas and households spend a high proportion of their income on domestic energy requirements (Eberhard, 1984b).

4.3 AGRICULTURE

Productive activity in underdeveloped areas revolves mainly around agriculture. Agricultural energy requirements are seasonal and this imposes limits on the energy options. One constraint seasonality imposes is the need to match power demand. It is not sufficient to have adequate energy if there is not adequate power to do the work in the time required. Energy must also be available in the season in which it is required.

4.3.1 PLOUGHING, CULTIVATING, HARVESTING

Much of the energy required for subsistence agriculture is human energy. It is fashionable to include estimates of human energy in energy budgets. These analyses are somewhat problematical for various reasons, which include methodological problems of measurement, extraneous factors which affect metabolic rates and qualitative differences between human energy and other mechanical energy sources.

If these problems can be overcome an energy and material flow diagram for a human community can contribute to an understanding of the use of resources by the community, to satisfy its basic physical needs, which would not always be possible with a conventional economic analysis. This is particularly true amongst agricultural communities in underdeveloped areas which live at or near subsistence levels where money exchange values are inadequate to map the flow of resources. An energy flow diagram can indicate those areas of the economy where technological innovation could play a part in the process of economic development.

The most comprehensive study of energy flows in human communities in underdeveloped areas has perhaps been made by Baily (1982). He calculated the average total energy content of all the food consumed by a village in Sri Lanka to be 9,9 MJ per capita per day, but that the energy content of the extra food required to perform the work of cultivation was only 0,65 MJ per capita per day. This may be compared with the total energy content of all the crops and crop residues produced in the village which was equivalent to 57 MJ per capita per day.

In a subsistence community in the Gambia the mean daily energy requirement calculated from energy output - (11 MJ per capita for men and 9,7 MJ for women) slightly exceeded the measured energy intake (Haswell, 1981). Thus when people were not working, metabolic rates had to be lowered and lethargy was substituted for leisure. People also optimised their energy usage by working long hours at a slow steady constant rate. When doing strenuous work like hoeing, rests taken in the field kept the energy cost per unit of time of all agricultural tasks more or less constant.

In these situations, replacing human energy by animal or inanimate power more than eases the drudgery and saves time; it allows other tasks to be carried out at a more energetic pace, saving even more time. The energy savings will allow people to spend their remaining time on productive non-agricultural activities or genuine leisure instead of lethargy.

Oxen are traditionally used for ploughing in Southern Africa. A viable subsistence herd providing milk, draught and breeding for replacement (but not sale or slaughter) would have to number nearly 20 animals. Only a small minority of households in the homelands have this number. Rangeland is overstocked so animals are in a weakened condition after the winter. Ploughing is sometimes delayed until oxen have built up their strength, to the detriment of yields. Even if oxen are shared or cows are used for ploughing, animals cannot do all the ploughing in the available time.

Minimum tillage or reduced tillage techniques can reduce energy requirements (Willcocks, 1983) but there will still be a need for tractors. Once the need for tractors is accepted, they should be used as widely as possible: for haulage, inter-row ripping, as stationary engines for milking and pumping and so on, so that they do not stand around idle for ten months of the year. A multi-purpose tool-bar was designed in Botswana with this in mind. In Kwazulu, it is noticeable that where there is a severe firewood shortage, tractors are easier to hire for ploughing than where wood is plentiful, because the additional business of wood haulage has entrenched the position of the tractor contractor.

4.3.2 MILLING

The annual maize production in Kwazulu for example is a little over 100 000 tonnes though given adequate support it could potentially be 340 000 tonnes (Erskine, 1982). Hand milling or stamping the latter quantity would place an intolerable burden on rural people. Alternatively small hammer mills driven by tractor engines would require roughly 0,8 million litres of diesel to do the job. Despite fuel costs this activity should be encouraged since it helps to optimise the use of tractors and avoids the unsatisfactory procedure of marketing maize through commercial channels and then reimporting refined maize meal. Insufficient attention has been given to alternative sources of power for milling except possibly pedal power, and this has not proved hugely successful (see below).

4.3.3 CURING AND DRYING

The curing and drying of produce demands energy and may lead to localised deforestation (e.g. fish drying by Sahelian communities or tabacco curing in Tanzania). There do not seem to be comparable examples in South Africa. Only minor quantities of energy go into preserving and curing agricultural products. Solar energy is a promising alternative for crop drying. However for curing, the action of phenolic compounds in smoke is important, and wood is irreplacable.

4.4 WATER PUMPING

Generally speaking, ground water should be used for domestic water requirements and surface water for irrigation and other agricultural requirements.

Ground water for domestic purposes can be obtained from a protected spring at no energy cost, or from a borehole where no perennial springs exist. Ground water can also be obtained from wells, but these are easily contaminated.

Let us take the case of Kwazulu where, at a guess, 1,5 million rural people are (or should be) served by boreholes. Generally the required flow rate will be too small to warrant a stationary engine. If typical 35 kW tractors were to power borehole pumps delivering 20ℓ per person per day (note that the World Health Organisation recommends 50ℓ) to these 1,5 million people, it would require about

1,5 million tractor hours per year using nearly R3 million worth of fuel. Engine power is clearly not appropriate as a complete solution, but some tractor power may make sense from the point of view of optimising the use of tractors already there.

Wind power is definitely appropriate for pumping in many situations (Ewens, 1984), as is human power if the required lift is not too great. However, boreholes put down in Kwazulu over the drought period of the last few years were fitted with commercially available hand pumps, and 60% of these are already out of operation. In some cases the reason was a falling water table, but most failures were a result of some design feature (some times very minor) which renders the pump unsuitable for that situation. Evaluation of handpump designs is urgently needed. A pedal powered pump designed at the University of Witwatersrand is currently undergoing field trials in Kwazulu (Rodd, Marcus and Kitshoff, (1984).

The example of handpumps also illustrates one of the reasons why poor communities do not get much benefit from certain technologies, even if these are appropriate and available. The reason is that maintenance is inadequate because one or more of the following three requirements is missing - tools, skills and appropriate social organisation.

There is a limit to the amount of patching up which can be done to subsistence agriculture. Sooner or later intensive methods will have to spread: for example irrigation where appropriate, and intensified livestock production which is also water demanding. For spray irrigation, some type of motor driven pump is required, but channel irrigation requires less power and options of energy source are much wider.

4.5 TRANSPORT

Transport is an important element in most aspects of rural life and needs. Commercial transportation, in the form of buses, taxis and trucks, is generally very expensive in rural areas and the rural poor bear the burden in terms of increased costs of essential supplies and personal travel expenses.

There is room for innovation in alternative forms of transportation. For example, the only concession the bicycle industry has made to rural needs here is a fat tyre for dirt roads. This is very meagre compared to some of the weird and wonderful pedal-power transport popping up in South East Asia and elsewhere.

Animal drawn transport is ideal for short haulage of moderately heavy loads. Cognizance needs to be taken of advances in more efficient harnesses which have been made elsewhere over the fairly primitive yokes which are still in use here. Some work has also been done (at the Thaba Tseka Rural Development Project) on the manufacture of low-cost ox-carts.

Transport requires infrastructure and energy is required to build and maintain roads, culverts, bridges, etc. The requirements can most appropriately be met by using low cost, low energy, high labour input methods such as those being implemented in the District Roads Project in Botswana and the Labour Construction Unit in Lesotho.

4.6 EDUCATION, HEALTH AND WELFARE SERVICES

Energy requirements for education provide one of the strongest arguments for electrification of rural centres. Electricity is required for visual aids and lighting for reading and studying in the evenings. Adult education classes are most conveniently held in the evenings, and given the structure of rural societies, this is arguably the most important and most neglected aspect of education for rural areas. Lapsed literacy is widespread because newly-literate people have no opportunity to practise their skills.

Electricity is also required for hospitals and the larger clinics to fulfil their curative functions. Preventative medicine has different non-electrical requirements: energy for sterilization of drinking water, and solar or paraffin powered refrigeration for storing vaccines.

4.7 RURAL INDUSTRY

Energy is required for processing and fabricating materials needed for house construction, household and agricultural implements, tools and clothes. Energy is required for small manufacturing facilities for commonly used devices such as bicycles or farm implements and also for their repair and maintenance.

An example of such a facility is the Rural Technology Unit at Thaba Tseka which provides a readily accessible service for the inhabitants of the district and repairs goods which would otherwise have been left in a state of disrepair because of the difficulties and cost of transporting and arranging their repair in urban centres.

Rural workshops and manufacturing facilities might require electricity for tasks such as welding and this could be costly depending on the extent of rural electrification or the availability of solar, wind or water resources to generate electricity. There are so many different permutations of workshop and manufacturing machinery and tools that it is difficult to generalize and estimate here the energy requirements for such facilities.

5 TECHNOLOGY TRANSFER

5.1 THE PROCESS OF TRANSFER AND DIFFUSION

There is no need to labour the point that appropriate technology must be compatible with social and economic conditions and with the resource base. There is not much disagreement on that. However, it must be emphasised that the adoption of technological innovation is a process, not an event, and the technology must be compatible with the process itself as well as the operating situation.

An example of a technology which has not proved to be very successful because it fitted the situation and not the process is the Tinkabi tractor designed in Swaziland. The situation was that people required draught power at the lowest possible cost, and the job could be done with low power output. The result was the ingenious Tinkabi tractor, low-powered, very economical and inexpensive, ultra-simple, made locally, simple to operate and requiring relatively low maintenance. A seemingly ideal solution until the process is examined. The tractor, cheap as it was, was still beyond the means of most farmers. The process by which mechanised draught power reaches the users is via a tractor contractor. The contractor wants to plough as many fields as possible in the ploughing season and so requires a more powerful machine than a Tinkabi. Had the process been understood and the time and effort which was spent on developing the Tinkabi been spent instead on developing ways to make tractors multi-purpose machines as we suggested above, draught power would be more readily available to the farming peasantry.

Self-help is a crucial part of development but it is incremental in nature. Technology transfer however is very often not incremental. Solar cookers for example require many major changes to be accepted simultaneously. Widespread dissemination of that sort of technology will require a large concerted effort involving education, extension and media support. Education undoubtably increases the willingness and ability to adopt innovations (Lyne and Kleynhans, 1983) although, it must be said, lack of education is sometimes unfairly blamed for failures which are actually a result of bad design.

5.2 CARRIERS OF TECHNOLOGICAL INNOVATION

Both a carrier group and a user group must be identified and understood, and the technology adapted accordingly. The carrier group is, as the name implies, the vehicle by which a new technolgy is introduced into and spread through a community. It may be an entrepreneurial group, extension workers, community leaders or teachers for example.

If a new device is truly appropriate, there will be a real (or latent) local demand for it. It should, if possible be inexpensive, based on components which are obtainable locally and be relatively simple to assemble. In short it might be ideal for exploitation by a local entrepreneur. If so, the design must take this into account, not only in the above features, but also the economics of small scale production, packaging, transportability, etc. The entrepreneur thus fulfils the role of carrier, manufacturing and/or marketing locally. A few jobs may be created where they are most needed. A good example in the field of energy comes from Kenya where water-driven grist mills are built, maintained and owned by entrepreneurs (Cook, 1980). In South Africa, a simple device for making dipped candles has proved economic and is disseminated through candle manufacturing co-operatives.

The rate of diffusion of an innovation is likely to be more rapid if it is done indigenously and based on incentive, than if it is external and based on persuasion as may be the case if extension services undertake dissemination. In the latter case there are large hidden costs in training and maintaining a field staff. In addition, extension services are often understaffed and overextended and not easily able to bear the burden of being carriers. One advantage of extension however, is that the cost to the user of the innovation can be kept to a minimum and in poor rural communities this may be a crucial factor, although the rural poor do not always opt for the cheapest option.

The example of fuel-efficient wood burning stoves illustrates this. The desirability of economising in the use of firewood is obvious: the choice of design of the stove and the type of material used is not clearcut. Mud stoves on the one hand cost very little or possibly nothing and are potentially within the reach of anyone but it is necessary to persuade people to build them, show them how to build one, then help them to build one. Simple as they are, hardly anybody makes a completely successful stove at the first attempt. The cost of disseminating the stoves will have to be borne by an extension or community development service since the stove is not transportable and cannot be made and marketed in the same way as a portable metal stove which could be made cheaply and locally from standard components (Shaikh, 1980).

5.3 THE NEEDS OF THE USERS

In another sense too, technology transfer is not an event. Thoughout the process there should be continuous monitoring and feedback allowing the technology to be adapted. It should evolve to fit a given situation. The acceptance of a new technological device may hinge on one or two relatively minor design features. Is is the type of development in which the action research approach should be applied, with designers, extension workers and users working together to meet users needs, as Joseph (1981) describes Intermediate Technology Development Group's stove project.

Again wood burning stoves provide a useful example. A survey of cooking habits in Mahlabatini District of Kwazulu (Gandar, in prep.) revealed that each household makes 2,5 fires per day heating an average of 5,4 pots per day. Eighty-eight per cent of the fires are made indoors. A need which was identified was the ability to heat more pots or containers both for cooking and for hot or warm water for washing, and there was a wish for an oven or at least some device for baking. The aim of stove design ought therefore to be not merely to save wood but also to do more with the wood available.

With 88 per cent of fires being made indoors, portability of a stove will be desirable but not essential though in warmer areas which are closer to 50:50 indoors and outdoors, portability will be a relatively more important criterion. Indoor fires also raise the question of exposure to smoke. On the one hand there is circumstantial evidence that wood smoke is involved in aetiology of some respiratory and eye diseases, but also helps to control insect pests indoors. Everybody seemed to be conscious of the danger of burns from open fires. Rural hospitals treat numerous cases of serious burns sustained particularly by young children. Safety will be an important criterion in the acceptability of a stove. Smokelessness and safety are matters which are more readily understood by uneducated people than concepts of thermal efficiency or conservation of energy.

Other factors to be considered are the social function of a fire as a focal point for the household, and the importance of space heating and of light provided by a fire.

Clearly there will be no universally acceptable stove for the Third World. The same will be true of most appropriate devices.

5.4 FILTER ANALYSIS

The very lack of universality in appropriate energy technology and the large number of localised and unquantifiable criteria makes conventional cost-benefit analyses meaningless on their own. It is impossible to find a single index on which to base a choice between two technologies. In filter analysis the technologies are subjected to a number of tests: Does it do what its meant to? Is it technically feasible? Is it appropriate from an economic view or from a socio-cultural view? Is it compatible with the carriers or with the users of the technology? It is analagous to passing the options through a series of filters and only those which emerge at the end might be considered appropriate. Forgetting just one filter may cause much wastage and embarrassment as the example below illustrates.

Some ingenious pedal-powered corn shellers and milling machines have been designed. Given the facts that these tasks can take up a lot of time and effort, that motorised mills are expensive, that pedalling is the most efficient way of utilizing human power and that standard and readily available bicycle parts can be used to make the devices, they seem to be an eminently sensible solution. However, one filter should have alerted designers to the fact that they would not be successful in societies in which men do not grind corn and women do not ride bicycles.

6 POLICY OPTIONS

6.1 INTEGRATION OF DEVELOPMENT PLANNING AND ENERGY PLANNING

Current energy planning, with its emphasis on large-scale, centralised power stations with their highly inequitable distribution systems, has proved inadequate for the needs of the rural populations in underdeveloped areas. The problem of rural energy supply for underdeveloped areas calls for a new approach and a new planning strategy, specifically orientated to the needs of integrated rural development featuring increases in agricultural production, encouragement of rural and small-scale industries, expansion of employment opportunities and provision of basic needs.

If development is to occur in depressed rural areas it will have to be sustained by an integrated rural energy system which would encompass all facets of rural energy supply and result in optimum matching of supply with energy requirements.

6.2 ALLEVIATING DOMESTIC ENERGY SHORTAGES

There are three ways in which domestic energy shortages may be alleviated: producing more firewood, using it more efficiently and adopting other forms of energy. Alternative energy sources may have important applications in specific situations and are definitely worth investigation, but will not have a great impact on the energy budget of rural households as a whole. Wood is convenient, relatively cheap, does not require fancy appliances and is renewable. It will be the primary domestic fuel for the foreseeable future. Stoves and hayboxes may reduce the amount of wood required for cooking, but until suitable stoves are designed for conditions here and disseminated on a large scale it is impossible to anticipate what the saving might be in reality (as opposed to controlled experiments in the workshop). Savings of up to 50 per cent are claimed to be possible with a Tanzanian designed stove (Anon, 1982), but with improper use of inferior designs the firewood situation can actually be worsened (Joseph and Shanahan, 1981). The importance of fire for space heating and its social function suggests that the savings will only be a small fraction of consumption, but even a few percent of 12 million m^3 of wood per year is still a huge amount of wood.

This leads us to the conclusion that the first option, that of producing more firewood, will have to be the main strategy but this also cannot be a solution in itself. It would require approximately one million hectares of plantation to provide for South Africa's firewood requirements on a sustained yield basis. At the moment, the extent of non-commercial plantation for firewood is less than 2% of this and over half of it is in Transkei. That leaves precious little for the rest. Much of it is degraded and neglected, and does not produce anything like its potential.

A woodlot programme, or the establishment of a single woodlot, ought ideally to be a community project, though community participation in itself is no guarantee of success (Gandar, 1983b). Woodlot programmes elsewhere in Africa with a high input of planning and management from outside have sometimes been successful but their expansion is limited by the management resources of the organization implementing the scheme. Sometimes the results have been disasterous and trees have been uprooted by the villagers. Community forestry, although a maze of do's and don't's and with a similar track record of frequent failures, has no theoretical limit except that imposed by land availabiltiy.

Land will be a crucial factor in any woodlot programme in South Africa. Under the present system of separate development and its associated legislation it is senseless to talk glibly about one million hectares of woodlot and, in fact, under any system it would be an excessive expectation. There is in fact no simple, single answer to the rural domestic energy crisis. We suggest that, in addition to promoting stoves and other fuel types, the following should be done:

1) Woodlots should be vigorously promoted, especially on steep or stony land where there will not be much conflict with food production.

2) Some of the principles of agroforestry should be adopted such as alley cropping (Harrison, 1982) and incorporating trees into every possible niche within the agricultural environment as has been attempted quite successfully in China (FAO, 1978).

3) The indigenous forest and savanna woodland should be used on a planned, rational sustained-yield basis. Indigneous vegetation supplies the bulk of firewood used at present and although it is severely over exploited with serious environmental consequences for some areas, it's use should not be entirely discouraged. It is traditionally a free resource and wood gatherers act as a brake on shrub encroachment of rangeland. The resource could be managed along the lines suggested for the Matsheng Villages in Botswana by White (1979).

4) Research is required on tree species and management systems which can optimize firewood production. Forestry research in South Africa has been aimed almost exclusively at the commercial sector.

5) Wherever economically feasible, forestry waste from commercial plantations should be used. This already happens on a limited scale mainly through informal sector activity.

6) Small scale commercial timber growers should be encouraged in the appropriate bioclimatic types. This happened more or less spontaneously in Reserve 4 of Kwazulu and the thinnings and harvesting waste from these small plantations provide the community with their fuel needs.

6.3 ALTERNATIVE ENERGY SOURCES

The need to explore alternative energy systems originates from the following considerations:

1) centralised power stations have generally not met rural energy requirements;

2) rural electrification based on centralised systems has tended to be inequitable in the distribution of power;

3) rural electrification through the extension of central grids is highly capital intensive;

4) rural populations are widely dispersed which results in increased transmission losses and costs;

5) renewable energy resources are diffusely distributed and are appropriately collected and exploited in decentralised systems; and

6) electricity is only one form of energy required for rural purposes.

Greater emphasis thus needs to be given in energy planning to the use of local systems involving the maximum use of solar, wind, water and biomass energy technologies. None of these technologies are currently very cheap and many investigations into alternative energies have unfortunately resulted in generalised conclusions that no renewable energies are economical. Many of these conclusions are the result of thinking based on experience with centralised power systems where any one renewable energy source is evaluated in terms of its potential to supply the electricity grid. But renewable energy technologies need to be matched to particular rural energy requirements. When this is done, there are many examples where alternative energy technologies may be appropriate. Some examples are anaerobic fermentation for the production of biogas, hydraulic energy for the production of electrical and mechanical energy, wind energy for the production of electrical and mechanical energy and solar energy for use as direct heat or for the production of electricity. Already hybrid wind/ diesel generating sets are cost competitive in remote rural regions and new advances in photovoltaic technology are resulting in major decreases in module costs. The latter technology is particularly well suited to decentralised energy collection in remote areas and is relatively maintenance free. What is needed is an energy mix which matches the most appropriate energy supply technology with particular energy requirements.

Here, we should dispense with two frequently held assertions regarding rural energy. The first is the condition of self-sufficiency. One problem is that the scale of energy autonomy is seldom defined: are households to be energy self-sufficient, or are villages, or regions? Rural situations ideally require a mix of energy types, not all of which are obtainable locally. The main goal of rural development must be to create viable sustainable rural economies. These will inevitably require imports of energy. Nevertheless, it is obviously desirable to make maximum use of indigenous energy resources. The second untenable condition, which is a product of the energy-for-subsistence paradigm, is that only renewable sources be used. Oil consumption is a relatively small part of the energy budget in underdeveloped regions and their oil consumption is only a small part of global oil consumption. We accept that it would be foolhardy to become totally dependent on a finite energy source which will rapidly increase in price, and that optimum and maximum use of renewable sources should be a national goal. However there is some truth in the statement that 'conservation may be the best demand option but there are a series of structural reasons why the developing countries correctly place the emphasis on supply (of oil) and leave conservation for the rich' (Hosier et al, 1982). South Africa has both energy-rich and energy-poor sectors so the issue is both one of demand options and of supply options; in other words a reallocation of resources.

6.4 RE-ALLOCATION OF RESOURCES AT NATIONAL LEVEL

The energy problems of underdeveloped areas are largely a result of historical processes and the development of economic structures which required the establishment of labour migration and the restriction of a large growing population to small 'homeland' areas. Acute pressures on resources in these confined areas results in scarcity of traditional energy sources, environmental degradation and human hardship.

Energy consumption in South Africa cannot therefore be divorced from patterns of development in South Africa and efforts to overcome energy problems in underdeveloped areas must involve the reallocation of resources at a national level. There is no overall shortage of energy in South Africa, only a highly inequitable distribution of and access to energy resources. If poverty in South Africa is to be tackled then the provision of energy for development in impoverished rural areas cannot be ignored.

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