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IN EAST AFRICA

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PREFACE

The idea of convening an International Workshop on "Energy and Environment in East Africa" dates back to 1978 when the Beijer Institute, Sweden decided to undertake some studies on energy problems of the developing countries. The programme of the workshop was then developed in co-operation with the Kenya Academy of Sciences and the United Nations Environment Programme.

The Workshop was convened in the period 7-10 May, 1979 in Nairobi and the discussions of the papers presented at the Workshop provided a valuable opportunity to exchange views on the energy problems of the East African region. Several inadequacies in our knowledge and action have been highlighted which has since then triggered several research and development activities.

The present report gives the papers presented at the Workshop and a summary of the findings. It should be noted that the views expressed in these papers are those of the respective authors and not necessarily those of any of the sponsoring organizations.

It is hoped that the dissemination of information contained in the present report will be of use, providing a "case study" of the energy problems of a sub-region in the Third World.

The sponsors of the Workshop would like to express their gratitude to Mr. P. Ndegwa, Economic Advisor, Office of the President, Kenya who during his work with UNEP and afterwards, gave all support and encouragement to convene the Workshop. The sponsors are also indebted to the Minister for Economic Planning and Community Affairs, Kenya, the Minister for Power and Communications, Kenya, the Swedish Ambassador to Kenya, and to the Secretary General of the National Council for Science and Technology, Kenya for their interest and support.

Essam El-Hinnawi
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UNEP

Nairobi, March, 1980

THE CHINESE DEVELOPMENT OF BIOGAS AND ITS APPLICABILITY TO EAST AFRICA

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SUMMARY

During the past 20 years China has developed a highly successful national biogas programme. The instructions for building, operating and maintaining biogas pits are contained in a single standard manual. This is described. The experience of Shachiao Commune in developing its biogas programme is described. The differences between Chinese and Kenyan conditions and the problems they cause in transposing the Chinese experience to Kenya are discussed. The areas most urgently needing further investigation are suggested.

The development of biogas is one of China's success stories, but it took twenty years. A national biogas programme was first publicised in 1958 when Mao called on local communities to produce and make good use of the biogas - 'marshgas' as it is known in China - that is generated as a by-product in the fermentation of agricultural and animal wastes. This was part of the movement to establish rural organisation through collectivising land and labour, and to step up the pace of development throughout the economy by making use of all potential resources.

It was not until 1970, however, and only in the mountainous province of Sichuan (Szechuan) that biogas plants were built at a rapid rate. By the mid-1970s the technique was spreading to other provinces so that the total number for the whole country had reached roughly 7,000,000 by mid-1978, ranging from individual family tanks only a few m^3 in volume to communal plants of 100 m^3 (New China News Agency, 23 August 1978).

Until recently little was known about how this was achieved. Recent and detailed investigations of the creation of a biogas programme in one commune in South China (van Buren, 1979), however, give a vivid picture of how the technique has been spread to new areas. The following description is based on an interview with Liang Daming, Head of the Biogas Works Office in Shachiao commune, Shunde County, Guangdong (Canton) Province, in September, 1978.

Shachiao is a large commune, embracing 72,000 people, divided into 25 production brigades, and subdivided into over 300 production teams. It is highly productive, specialising in scientific experimentation in aquaculture - exporting 15 tons of carp per day to the city of Canton - in silk worm raising, in sugar cane, and in recycling organic wastes.

In 1976 Guangdong Province sent three people from Shachiao to Sichuan to acquire and bring back the expertise necessary to set up their own biogas programme. Of the three, only one had building experience. Liang Daming and the third had been employed in the commune's commercial goods distribution department. None of the three had any previous training in or familiarity with biogas.

On the train to Sichuan, they read a technical manual on biogas - the only book they consulted - which is the primary one published on the subject and available in bookstores throughout the country. It is one of the 'Science in the Countryside' editions of books and manuals particularly suited to rural needs, derived from rural experience, and designed to make techniques and fields of learning accessible to people with little education beyond literacy. It is remarkable that for each subject the technical details, principles, precautions, and solutions appear to be contained in a slim handbook.

In the biogas manual, the explanations are extremely simple and meticulous: how to draw a plan, how to apply mortar in paper-thin coats, how to build a dome of bricks. The appendices provide basic geometric formulae, as well as the composition and proportions of the various cements and mortars used in building the different kinds of pits. The language is simple and inspires confidence, but emphasises that a biogas pit is not easy to build. The book is compiled from previous experience in Sichuan and is meant to short-cut much of the experimentation and errors that were made there. Yet according to the Shachiao Biogas Office, it is impossible to adopt the technology without adapting it to local conditions. Chinese criteria for success require the plant not just to function, but that it be made as much as possible from local materials to reduce costs.

The book begins by describing the physical and chemical properties of biogas and its numerous advantages. Biogas will help alleviate rural fuel shortages by providing an inexhaustible source of energy; it saves coal, oil, and electricity for the state; it decreases the demand for firewood and thus furthers efforts at afforestation; it stimulates rural productivity and promotes rural co-operation; and it permits its users to spend elsewhere the money and effort they would have spent on buying and transporting fuel.

But biogas was developed in China not primarily as a source of fuel. A far higher priority, in fact, is given to its role in rural health. Fermenting organic wastes in a sealed pit destroys 95 per cent of the pathogenic microorganisms they contain*. In each area of China where biogas has been developed, schistosomiasis and other parasitic diseases have been effectively controlled.

The other major benefit of the technique - once again put in higher priority than energy - is that it augments and improves organic fertiliser for agriculture. Composting wastes in an air-tight biogas pit transforms their nitrogen into ammonia which is easier for plants to assimilate, and preserves that ammonia by preventing evaporation.

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* For more detailed information than appears in van Buren (1979), see McGary and Stainforth (1978).

The Canton Agricultural Institute has reported a 150 per cent increase in ammonia content over the same period against an 85 per cent loss through evaporation when merely composting in unsealed heaps.

Various experiments on the increase in agricultural yield are recorded in the book. Particularly relevant to semi-arid East Africa is the humus value of the organic fertiliser. The slurry from a biogas pit produced the following increases over the direct application of manure to the fields: 28% more maize, 10-15% more rice, 15% more wheat, 25% more cotton, and a 25% increase in the yield of green vegetables.

The manual, however, concentrates on the technology for the production of gas. Biogas is a high quality fuel. One cubic meter can provide lighting equivalent to 60 watts for 6-7 hours and can cook three meals for a family of five to six. It can run a 1 hp. internal combustion engine for two hours, is equivalent to 0.6-0.7 kg. of petrol and will drive a three-tonne lorry for 2.8 km. and can generate 1.25 kwh of electricity. It can also be used as a petrochemical feedstock.

The book outlines the conditions necessary for a good gas yield:

1) absolute airtightness for anaerobic fermentation.

2) a constant temperature: a range of 10-30°C is most common, although higher temperatures are possible.

3) plenty of fermentation material with a carbon/nitrogen ratio between 20:1 and preferably consisting of more than one type of organic material.

4) sufficient water, amounting to 90% of the pit contents by weight.

5) a suitable pH balance in the range 7.0-8.5.

6) a strict avoidance of harmful chemicals above the maximum allowable concentrations listed in the manual.

The book describes 14 variations on the basic design of the pit, each one specific to local geological conditions and material availability. These types vary from rectangular pits built only of concrete, to spherical ones of brick, to directly tunnelling into sheer rock. Because these designs were evolved in a mountainous area, the manual is used in other parts of the country primarily for the principles, approach, maintenance and operation. The pits at Shachiao, 1,000 miles away and by the sea, illustrate how much the method of construction may have to change for a different geographical setting. The manual stresses that the type of pit and its construction should be developed according to local conditions and by the people building it, and that outside support, both technical and financial, should be strictly subsidiary. This was strongly supported by the Shachiao Biogas Office.

The Chinese system uses metal and plastic only for piping and valves. The structure is completely made of stone, cement (either commercial, or home-made of lime, sand and mud), brick, or directly carved out of a layer of solid rock. The material cost ranges from 1 Yuan (2 Ksh) per cubic meter ($1m^3$ is required for every person using the gas) for home-made cement, to 5-6 Yuan (10-12 Ksh) when using commercial cement. For a $7m^3$ pit, the materials cost 7-40 Yuan (14-80 Ksh). But these costs cannot be directly translated into other currencies, because of the great difference of Chinese wage and price structures. An average industrial wage is 70 Yuan (140 Ksh) per month, but in the countryside wages are much lower and are supplemented by an allowance of grain and meat; families have private plots for vegetables and the produce can be traded or sold; full medical care is available at negligible cost. In assessing the cost of building a biogas pit, it is the labour time which is significant. Thirty-five working days, which can extend well beyond ten hours each, are required to build a $7m^3$ pit for a family of seven. (This, however, is seen by the Chinese not as a cost but rather as an investment, a building up of technical expertise)

The second half of the manual covers maintenance of the pit and appraisal of its quality. Meticulous tests must be made for airtightness and watertightness by means of a manometer, by smoke, or with dry plaster. Common causes and locations of leakage are described and matched with methods of repair.

Then comes the section most relevant to the existing biogas plants in Kenya, on the scientific management of pits. The over-riding principle is that "the use of gas, the collection of manure, the treatment of sewage and the use of slurry on the fields must all be properly integrated in order to provide fertiliser for agricultural production and gas for domestic needs."

The fermentation material must be properly mixed for the correct ratio of carbon to nitrogen, in order to ensure full gas production. Dry straw and other stalks have over 50 units of carbon to one of nitrogen, while fresh human excrement has a ratio of 2.9:1 (Table 2). A mixture is necessary to produce the optimum ratio of 20:1-25:1. While fresh cow manure with a ratio of 25:1 is virtually the only source for biogas generation in India and Africa, Chinese experience has found that fermenting a single kind of material generally gives poor results. The most common proportions used are 10% human excreta, 40% animal manure and crop residues and 50% water. The main point again is that the mixture must be selected according to local conditions to make efficient use of available materials.

TABLE 1. Gas Yield of Some Common Fermentation Materials

Material	Amout of gas produced per tonne of dried material in cubic meters	Percentage content of methane
General stable manure from livestock	260-280	50-60
Pig manure	561	
Horse manure	200-300	
Rice husks	615	
Fresh grass	630	70
Flax stalks or hemp	359	59
Straw	342	59
Leaves from trees	210-294	58
Potato plant leaves and vine, etc.	260-280	
Sunflower leaves and stalks	300	58
Sludge	640	50
Waste water from wine or spirit making factories	300-600	58

TABLE 2. Approximate Values for the Carbon/Nitrogen Ratios of some of the Common Materials used for Biogas Pits.*

Material	Carbon as a per centage of total weight %	Nitrogen as a per centage of total weight %	Carbon/ Nitrogen ratio %
Dry straw	46	0.53	87:1
Dry rice stalks	42	0.63	67:1
Maize stalks	40	0.75	53:1
Fallen leaves	41	1.00	41:1
Soya bean stalks	41	1.30	32:1
Wild grass, i.e. weeds etc. (in China often narrow thin leaved)	14	0.54	27:1
Peanut vine stalks	11	0.59	19:1
Fresh sheep manure	16	0.55	29:1
Fresh cow/ox manure	7.3	0.29	25:1
Fresh horse manure	10	0.42	24:1
Fresh pig manure	7.8	0.60	13:1
Fresh human manure	2.5	0.85	2.9:1

* Pyle (1978) gives the following C/N ratios:

Material	N % Dry Weight	C/N Ratio
Night soil	6	6-10
Cow manure	1.7	18
Chicken manure	6.3	7.3
Horse manure	2.3	25
Hay, grass	4	12
Hay, Alfalfa	2.8	17
Seaweed	1.9	79
Oat Straw	1.1	48
Wheat Straw	0.5	150
Bagasse	0.3	150
Sawdust	0.1	200-500

From the discrepancies, it is obvious that C/N ratios need to be established for local materials.

Finally, pH and temperature must be kept constant, the latter by insulating the pit in winter with a covering of straw or earth. Pits directly linked to toilets and pigsties are kept warm by a steady inlet of fresh material and in winter only need a cover over the outlet compartment.

The construction and installation of appliances to use the biogas, mostly made extremely simply out of bamboo or clay, are described in detail. The last chapter discusses accident prevention and safety education.

This then was the reference book for the three who went to Sichuan. There they stayed 15 days with families who were building and operating biogas pits.

Immediately after returning, they built the first pit at Shachiao. It took over one month to build and was a success. They then built four more, three of which succeeded and one failed. Unlike the mountainous terrain of Sichuan, Guangdong lies very close to sea level. The high water table forced them to abandon the use of home-made concrete because the lime which acts as the bonding material for the sand and mud in the traditional mixture was causing their pits to leak. Instead they had to substitute grade 400 commercial cement, despite their preference for lime because it is cheaper.

A new technique of pit construction was invented, with the bottom part of the pit pre-cast in concrete in a hollow carved to the right shape out of the soil at ground level <u>above</u> the water table.

The resulting concave concrete dish can then be floated, and positioned above the hole. When the water is then pumped out, the dish comes to rest in place at the bottom of the hole. A cork is then removed from the centre of the dish, so that it will not float upwards as the water seeps back into the hole. With the concrete dish as a firm base to stand on, workers can then proceed to build up the brick walls of the pit along the rim of the dish. Heavy clay is packed over the top of the completed fermentation tank to increase the downward pressure on the pit. Enough water is kept in the pit at all times to prevent floatation.

When the construction technique had been perfected, demonstration pits were built. The building team invited the leaders of the commune, and of the brigades and teams, to observe them in operation. They took great pains to explain the benefits of biogas development. After the demostration, these leaders seized every opportunity to relay the message, in order to overcome people's suspicion that the biogas and slurry could cause disease. Whenever they had a meeting they would say a few words about it. They drew big charts, made plans in the teams and brigades, paid visits to the homes of families to explain to them why they should do such a thing, and "gradually people changed their outlook and resolved to give it a try".

A team of 70 technicians was trained, among whom only a few were builders by trade. This required each person to learn the whole process and everyone to build with their own hands, so that after a year they had all become builders and experts. The 70 were chosen according to their sense of responsibility for the brigade and team, and their understanding that at the end of their training, they had to be qualified, and that failure was not an option.

Under the supervision of these technicians and the original experimenters, the brigades and teams undertook an active construction programme. They assembled the materials and people to build a pit in each brigade so that these could acquire the experience through doing it themselves.

Experiments which had first been organised at commune level spread to brigade level where each brigade leader was held responsible for building his own pit - this was one of the most important steps in popularising the technology throughout the commune and eventually down to the individual household.

By the end of 1976, several months after the programme's inception, 100 pits had been built by the brigades. By the end of the following year, another 600 were in operation. By September 1978, just two years from when they first began learning about biogas, there were 1,640 pits in the commune, of which 1,300 were built by individual families. Liang attributed this impressive achievement to their adaptation of the construction principles to their own circumstances; the technology was not merely transferred but completely transposed.

These pits range in size from $3m^3$ to $64m^3$. The individual family pits are usually 5-$7m^3$; the collective pits 30-$40m^3$ in volume. The former are used to produce fuel for cooking and lighting and for fertiliser; the latter are used to generate electricity for irrigation and pumping, for grinding pig fodder, and for lighting in the silkworm houses, with fertiliser again the other important product.

The 70 technicians are now in charge of safety and management, working full-time to check on maintenance, help with repairs, and generally be at the disposal of anyone having problems with a pit. In addition, they have passed this expertise on to another 300 people who perform this service part-time.

Families are themselves responsible for collecting dung to feed into the pit (which they said took no longer than the time to smoke a cigarette!), for feeding it in, and for letting out gas according to the pressure gauge in their kitchen. Removing the slurry for fertiliser is the responsibility of the production team.

Liang identified two decisive factors for proper gas production: ambient temperature and the combination of materials fed into the pit. As a rule of thumb, the more organic the contents, the more gas is produced, and the more nitrogen, the better the fertiliser. One cubic meter of pit volume can produce 0.15-0.20m^3 of gas per day at 25-33°C ambient temperature. Above 30°C the same volume can produce 0.3m^3 per day. On the average, the internal pit temperature is about 5°C higher, but this depends on the water level around the pit; water will absorb and draw off heat if the soil is sandy. At Shachiao the dense clay, however, prevents heat loss being a significant problem. Liang does not foresee that they will have many problems, except that the plastic they use for the pipes and taps is expected to harden and will have to be replaced every three years or so.

Transposing the Technology

Certain distinctively Chinese features have made this development a downhill path: a) Patterns of land tenure, of density and organisation in the population, and of social security are probably the most potent factors working in China's favour. All land is collectively owned except for the private garden plot; and the communal land is intensively farmed and populated so that the location of resources is known and exploited to its utmost. Population is relatively static and highly structured. There is no option other than the common goal. Once that goal is agreed, constructing and maintaining the necessary equipment poses no problem: This is immensely aided by the existence of collective financing and central planning and political discipline.

b) The climate and geography are ideal for biogas, to which the natural occurence of 'marshgas' testifies. In tropical South China there is year-round vegetation, ample water supply and high ambient temperature.

c) Manure is plentiful and accessible. The pigs which are confined and numerous are called miniature fertiliser factories. They live well in pens and feed off a variety of vegetable wastes.

d) In China there is a long tradition of using human waste in agriculture. Its introduction into a biogas pit does not therefore go against social taboos; on the contrary, is helpful in breaking the epidemiological cycles of water-borne diseases.

Initial development of biogas is thus facilitated by a high degree of organisation in rural China, and its operation is perpetuated by the ease of material collection and by a tradition of concentrating agricultural wastes for disposal and recycling.

When Kenya is compared with China, most of these factors are found to be absent:

1) The rural population lacks the hierarchical, tightly organised structure of Chinese communes, and is scattered over large areas. About 80% of Kenya's population lives on land holdings only 2.3ha in size (King 1978). Annual incomes are now, and the capacity to invest is extremely restricted.

2) In a semi-arid climate, water and vegetables are not as freely available.

3) Cattle are very few per holding, due to forage and labour shortages; but due to shortage of land in most parts of Central Kenya they are zero-grazed and paddocked at night (Muthee, 1978). The resulting manure concentration, although less than in pig farming, would seem to be sufficient to permit collection for biogas generation. Adverse factors, however, would be the labour required and the amount of microbiological action that will already have taken place before the manure reaches the pit.

4) In Kenya the use of human excrement is not practised in agriculture and there may be insurmountable difficulties in utilising it for biogas production. But contrary to widespread belief, human waste is not essential to biogas. Moreover, its disposal need not be a primary motivation because water-borne cyclical diseases are not such a problem in Kenya.

It has been said that the main impediments to individual acquisition of biogas plants in Kenya are the capital cost of the digester and insufficient cow ownership. Muthee (1978) assumes that a minimum of five cows are necessary and that the minimum cost of a digester is Ksh 3,000. Faced with the cost of such commercially available digesters, numerous authors have concluded that work should concentrate on community plants instead (Subtamanian, 1978). Those marketed in Kenya by the Hutchinson Tunnel Company, made of corrugated metal , have only proven economical and successful in the larger 20-cow sizes (Pyle 1978).

As details of the Chinese versions become known, it appears that the digester can actually be built very cheaply from local materials. Furthermore, the feed need not be limited to a single material, and if diversified, is better co-ordinated to agriculture. This manual is the first to give details of the different designs and of the method of operation. If the digester can be built more cheaply, if it does not depend for feed on cow manure alone, or if it can operate effectively with fewer animals, then it becomes an option for the individual farmer in Kenya. A programme of investigation can perhaps be prepared on the basis of the Chinese manual.

A strong case has been made for building the plants not out of importedmetal but out of hewn stone (Pyle 1978) or discarded oil drums (Hanlon 1978). The Chinese designs would also suggest considering concrete or bricks (made of local clay or of concrete), or cutting directly into a stratum of rock. These methods are costly in labour but cheap in materials which are derived locally whenever possible.

It has been said that there is far less tradition in Africa to support a design based on bricklaying than one built directly of concrete (Ahman, 1979). This would argue for experimentation with different concretes, particularly with inexpensive home-made varieties of lime, sand and clay as described in the manual.

In the Chinese designs being built at the Rural Industries Innovation Centre in Botswana, the main construction difficulties have occurred in making the dome to the tank strong enough to withstand the high pressure from within the pit (Ahman, 1979). Structural experimentation will therefore probably be necessary.

The Chinese system recommends using more than one type of material for fermentation and is fundamentally a means of comprehensive agricultural waste disposal. From Table 1 it is clear that crop residues must be balanced by animal wastes with low C/N ratios.

Serious attention should be directed to diversifying fermentation material in Kenya, to give the biogas tank a more central role in agriculture and use it to recycle organic nutrients to the soil. Increasing the quantity of available humus gives the biogas system an even greater value in hot semi-arid areas where bacterial activity in the soil is so rapid that humus tends to be burned up quickly. If crop wastes can be used to produce biogas, animal wastes should be selected accordingly to produce the proper mix for fermentation.

In order to be able to make use of human excrement with its low C/N ratio and bypass taboos against handling it, channels should be built to allow it to flow directly from latrines to the biogas pit. Alternatively crop wastes could be composted to reduce the C/N ratio and require less animal manure. The feasibility of increasing pig-raising or collecting chicken manure should also be considered.

Water is the other crucial element for fermentation and must be plentifully available. Outside Central Kenya and in the more arid areas, it is scarce and the value of its use for biogas must be weighed against alternative uses. The best approach would be to integrate the development of biogas, pumped water supply and controlled latrine provision. At the RIIC in Botswana, it has been acknowledged that the three go hand-in-hand in a comprehensive system of rural sanitation.

Whereas the gas can be valued with a fair degree of precision, consensus on the value of the slurry is totally lacking (Pyle, 1978). The results of Chinese experiments on agricultural yield are only sketchily recorded in the manual, and dependent upon a number of specific variables. A top priority in a national biogas programme for Kenya would be to carry out extensive experiments to measure the yield of crops grown with the slurry, as compared to applying dung directly to the fields or as compost and then compared with the yield from chemical fertilisers.

Labour is the largest factor in designs using local materials. In China it is regarded not as a cost but as a contribution by the future owners of the plant, and as a necessary acquisition of the expertise required to master the technique. They specifically expected all pit builders to engage in every aspect of planning, design, construction and maintenance in order that they become competent over the wide range of skills involved. Is it realistic in Kenya to regard labour not as a drain on human resources but as an investment? The degree of self-employment, of available unused labour, and the opportunity to put that to productive use will determine whether such a labour-intensive, small-scale form of the technology is in fact feasible.

Finally, there are the social and organisational considerations. The population density and permanence are of major importance in developing biogas, and determining whether it should be communal or individual. The distribution of benefits from communal pits is a difficult problem and projects may founder unless it can be resolved satisfactorily.

There may be a need for the state to create and guarantee essential technical support in the form of teams of technicians in a biogas extension service, to teach the methods, supervise construction and be available for assistance when problems arise. The lack of technical support for operation and maintenance seems to have been the primary cause behind the failure of three-quarters of the plants installed in Kenya (Pyle, 1979).

Existing institutions should be examined for their adequacy in technical support and education, their ability to offer financial assistance, and their contacts with other organisations that are building up a body of East African experience in biogas, such as the Arusha Appropriate Technology Project in Tanzania and the Rural Industries Innovation Centre in Botswana.

China has demonstrated the undoubted potential of biogas. The attractions of a similar development in Kenya is obvious, but circumstances are different and the problems are not only technical and economic but social as well.

It is essential to integrate the operation of biogas into traditional patterns of farming so that the residues from agriculture feed into the generation of biogas and the slurry produced is used as fertiliser. Unless these two systems can be matched, no matter how perfectly the technicalities are worked out for Kenya, a biogas programme will not survive.

REFERENCES

Ahman I, (1979) — Head of Section for Water and Sanitation Development, Swedish International Development Authority (partial sponsor of the Rural International Innovations Centre, Botswana); personal communication.

Hanlon J, (1978) — "Not Just Another Windmill", New Scientist, 14 September. p.756.

King R.P., (1978) — The Development of Biogas - Slurry Plants and Systems in Kenya, mimeo report, Department of Agricultural Engineering, University of Nairobi, Kenya. June 1978.

McGary M, Stainforth J, (1978) — Compost, Fertiliser and Biogas Production from Human and Farm Wastes in the Peoples Republic of China. International Development Research Centre, Ottawa, Canada

Muthee A, (1978) — The Role of Biogas in the Rural Energy Package. Biogas Seminar, Egerton College, Njoro, Kenya. 5-8 September.

Pyle D.L., (1978) — Energy and Fuel from Biomass. National Energy Symposium, National Council for Science and Technology, Nairobi, Kenya. 22-24 November.

Subramanian (1978) — in Barnett A, Pyle D.L., Subramanian SK (1978) Biogas Technology in the Third World, International Development Research Centre, Ottawa, Canada.

van Buren E.A. (1979) Ed. — A Chinese Biogas Manual, translated from the original. Intermediate Technology Publications.

ENERGY FUTURES IN DEVELOPING COUNTRIES

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SUMMARY

The important role played by energy in a country's development is universally recognised. Consumption of energy has been growing steadily in the past three decades and the same general trend is expected in the future. This steady growth will have to be balanced against the availability of energy resources. In analyzing energy requirements and prospects a number of points emerge. First, there is a wide disparity in energy consumption between the developed and the developing countries: with more than two-thirds population, the developing countries together consume less than 20% of the world's total commercial energy. There are also wide disparities in consumption levels and rates within developing countries - depending on size, level of industrial development etc. Second, with higher population growth rates, faster rates of industrialisation and more pronounced shift from traditional sources of energy to commercial sources, the rate of consumption of commercial energy has been increasing faster in the developing countries, and soon the developing countries will command a sizeable share of energy consumption; their share will be increasing during the period when conventional sources of energy, notably petroleum and natural gas, are expected to be dwindling. The implication of this state of affairs need more attention than has so far been the case. Third, energy problems of developing countries are closely tied to those of the industrialised countries. Policy decisions on energy taken in the industrialised countries have a direct or indirect bearing on energy issues of the developing countries; and since 1973 major policy decisions taken by a group of developing countries have had a marked influence on the direction of development in energy matters in the industrialised countries. Energy issues are thus part of a global problem and must be seen and resolved as such. Fourth, as noted above the world is or will soon be going through a critical time in energy resources development and utilisation: the transition from a fossil fuel energy base to another, as yet undetermined base. The social and other impacts of such a transition are yet to be assessed. Of immediate importance to the developing countries but less talked about is a relative issue; forest resources are being used at a much faster rate than they are being replenished; and unless drastic steps are undertaken, the consequences will be more serious and much wider than the question of adequate availability of an energy resource. Fifth, at the present time, many developing countries are faced with a wide spectrum of problems, that must be addressed to and resolved if they are to attain and maintain a reasonable balance between energy requirements and supply in order to sustain sufficient levels of industrial and economic growth. The problems include inadequate financial resources, lack of skilled technical and managerial manpower, inadequate policy guidelines for the formulation of a viable energy resources development strategy. Sixth, exploration, production and mining, processing transportation and use of energy produce adverse impacts on the environment, the impact varying according to the energy sources. It is imperative to pay special attention to environmental factors during the process of evolving viable energy development strategies; for the cost of neglect or inattention to these factors may

turn out to be dear, indeed. Seventh, increasing attention is being given to the development of new technologies, for harnessing new and renewable sources of energy, including solar, wind, biomass, geothermal, oceanthermal, tides, waves etc. But not enough has been done. There are major gaps in knowledge of these technologies, of their operating experience and of their applicability under varying conditions, especially those obtaining in the developing countries. And lastly, an item that has received only casual attention in many developing countries: energy conservation and efficiency of use. The importance of energy conservation cannot be over emphasised. But in order to be effective, the question must be addressed to and tackled in a systematic way as part of an overall energy development strategy.

INTRODUCTION

That energy plays a crucial role in the economic development and well-being of a country, be it industrialized or developing, is a universally acknowledged fact. The demand for energy has been growing steadily the world over in the last 25 or so years in response to rapid industrialization, growth in populationm increase in per capita income and better living standards. Consumption has grown much faster in the developing countries.

The demand has been met by the production and development of conventional sources of energy including coal, petroleum, natural gas and hydroelectric resources. In the rural and to some extent urban, areas energy demand has been met by non-commercial or traditional sources of energy including wood fuel, charcoal, plant and animal wastes.

There has, over the years, been steady increase in consumption of petroleum and natural gas and concomitant reduction in the share of coal as an energy source, largely because of convenience of use and relative ease of transportation of long distance, in particular petroleum. It is, however, difficult to project how far into the future this trend will be maintained. The trend will undoubtedly be influenced by comparative price advantage of one energy source in relation to another and by technological advances and how these in turn bear on availability, production, conversion and ease of use of the particular energy source. An important and decisive factor will be whether or not petroleum and natural gas will be available in adequate quantities to meet the ever-increasing demand for these resources. Many analysts believe that petroleum and natural gas resources will soon run out. Many others, while accepting the inevitability of these resources running out one day, nevertheless believe that one day is still long into the future.

Energy consumption in the developing countries has also been accompanied by shifts away from non-commercial forms, a trend that is likely to continue long into the future as the standard of living improves and as more and more people move from rural areas to urban centres where existing structures of energy systems depend on the use of commercial sources of energy. The rate of growth in energy consumption in the developing countries is thus likely to maintain the level characteristic of the past two decades.

Increasing attention is being given to research development and application of technologies for the harnessing and utilization of new and renewable sources of energy notably solar, wind, biomass, geothermal, oil shale and tar sands. Many of these resources are abundant and widely distributed throughout the globe. Some like solar, wind and biomass lend themselves for convenient application in the rural areas of the developing countries where loads are dispersed and are thus decentralized. But many of these technologies are as yet not economically competitive with alternative sources of energy such as coal and petroleum. Many lack simplicity that is essential for their application especially in rural areas where most of the population have minimum technical training and know-how. The above misgiving apart, it is expected that with increased research and development effort, more technical and economic equipment and systems, within the reach of populations in the developing countries, will be developed.

With the expected increase in the demand for energy, especially so in the developing countries concern is being aired, with increasing frequency, on the adequacy of energy resources, notably petroleum and natural gas, to meet the future demand. The finiteness of these resources is not in question; that is an accepted fact. The point of departure is how long it will take before the resources are depleted, and here there are as many estimates as there are analysts. The expressed concern should hopefully help get over the euphoria of ever-abundant and cheap energy resources. It should prod us into embarking on the development of renewable energy resources and technologies for harnessing these resources. It should also force us to use energy more efficiently and institute appropriate energy conservation programmes; and above all it should force us to take definite steps to formulate and implement energy planning strategies that ensure the most effective use of energy to further the goals and objectives of the country's overall development.

The paper briefly outlines past trends in energy consumption in the world with particular reference to the developing countries. Probable trends of future energy demand and factors likely to bear on these are next discussed. This is followed by a brief summary of the energy resource base of the developing countries. Particular attention is given to research and development requirements for exploration, production, processing and distribution of conventional energy resources and for the development of new technologies for harnessing new and renewable sources of energy.

CONSUMPTION

The consumption of commercial energy (coal, petroleum, natural gas and hydraulic) in the developing countries rose from 139 million metric tons of coal equivalent (mtce) in 1950 to 846 mtce in 1976, corresponding to average annual growth rate of over 7.0 per cent. This was higher than the average for the world as a whole of 5 per cent per annum (2493 mtce in 1950 and 8318 mtce in 1976). As can be deduced from Table 1 growth rate in the developed countries was substantially lower, about   per cent per annum.

Growth in electricity consumption in the developing countries was much faster; rising 46.667 x 10^9 kwhr in 1950 to 605.497 x 10^9 kwhr in 1976 representing an average rate of about 10.3 per cent per annum. Corresponding rate for the developed countries was about 7.0 per cent per annum. (Table 2).

There is and has been, however, a wide disparity between consumption levels in the developed countries on the one hand and developing countries on the other hand. Thus, in 1950 the developed countries accounted for about 75 per cent of total commercial energy consumed while the developed countries accounted for only 5.6 per cent. The situation has not improved that much; for example, in 1976 the developing countries' share had risen to only 10 per cent, compared with about 59 per cent for the developed countries.

A look at per capita energy consumption, Table 3 also reveals the disparity between developing and developed countries. In 1950 per capita consumption in the developed countries was about 25 times higher than corresponding average in the developing countries. While the situation has improved considerably over the years - the ratio coming down to 15 times in 1976, there is still a long way to go before developing countries can attain consumption levels that are comparable to to those of the developed countries.

There are also large disparities within the developing countries. For example, consumption levels of Brazil or India are many times higher than those of, say, Nepal or Chad.

It should be emphasized that a significant portion of energy consumed in the developing countries is supplied form the so-called non-commercial sources of energy including wood fuel, charcoal, plant and animal waste. No exact figures are readily available; but the contribution form the non-commercial sources may be as high as 40 per cent for some countries. This partially accounts for the low levels of commercial energy consumption when compared with those of the developed countries, which in effect depend almost entirely on commercial sources of energy.

Table 1. Commercial Energy Consumption

(10^6 Metric Tons of Coal Equivalent)

	World	Developing Countries	Developed Countries
1950	2,493	139	1,864
1955	3,243	203	2,263
1960	4,243	286	2,609
1965	5,212	389	3,274
1970	6,782	569	4,306
1975	7,877	789	4,640
1976	8,318	846	4,902

Source: United Nations World Energy Supplies, Series J, No. 19 and No. 21.

Table 2. Electricity Consumption
(10^9 kwhr)

	World	Developing Countries	Developed Countries
1950	959.166	46.667	772.486
1955	1,543.236	78.553	1,069.784
1960	2,300.988	130.925	1,561.340
1965	3,380.786	211.350	2,406.625
1970	4,908.421	347.400	3,478.366
1975	6,459.741	551.981	4,374.169
1976	6,914.824	605.497	4,663.504

Source: United Nations World Energy Supplies, Series J, No. 19 and No. 21.

Table 3. Per Capita Consumption
(In Kilograms)

	World	Developing Countries	Developed Countries
1950	1,004	127	3,223
1955	1,196	169	3,681
1960	1,423	211	3,995
1965	1,587	254	4,717
1970	1,881	3,311	5,921
1975	1,996	406	6,089
1976	2,069	426	6,388

Source: United Nations World Energy Supplies, Series J, No. 19 and No. 21.

END USE

The end use patterns vary considerably from country to country depending on size; level and rate of economic development structure and level of industries and rate of industrial growth; in particular energy intensive industries; customs and life styles in so far as these can be reflected, directly or indirectly in the use of energy; availability and form of energy resources.

Figure 1 gives a general picture of energy sources and conversion stages through to end use (UNECA, 1975). It is given only for illustrative purposes and does not apply to any particular developing country.

The consumption of commercial energy has been concentrated in the urban areas, where the pattern of energy consumption is essentially similar to those of the industrialized countries albeit on a smaller scale. No data is available on a country by country basis. But in instances where data is available or can be derived, transport sector seems to account for a significant share of commercial energy as does industry.

Figure 1: ENERGY CONSUMPTION—ALL FUELS

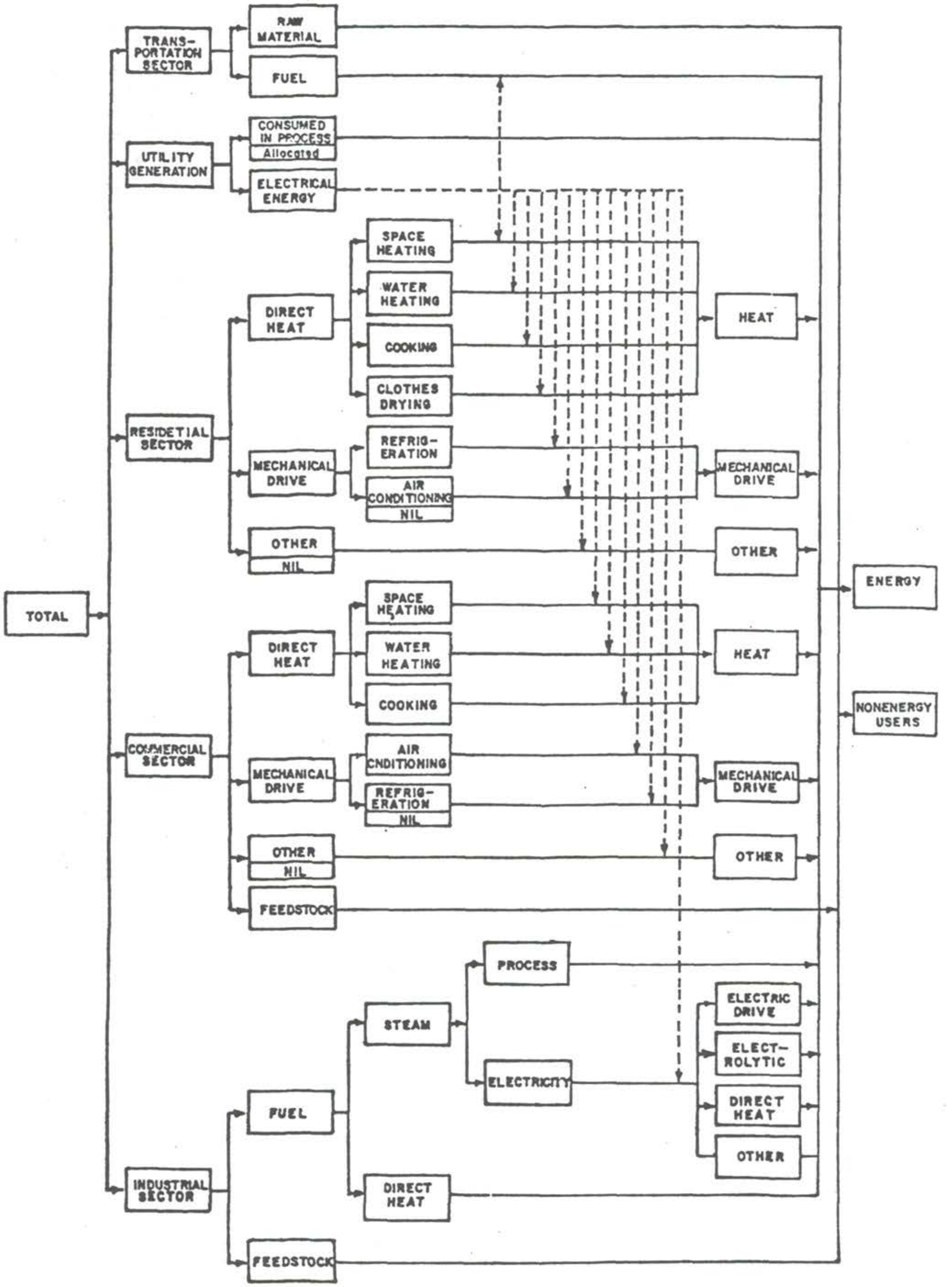


Table 4 with data on commercial energy use for India and Mexico illustrates patterns of commercial energy use (UNCTAD, 1978). Germany and USA are given for comparative purposes. The similarity in energy use patterns in both India and Mexico are not accidental: both are relatively more developed. The pattern of commercial energy consumption is strongly based towards the use of oil. As is the case in the developed countries, indeed more so, the share of oil in relation to coal has increased steadily over the years, accounting to more than 60 per cent of the total commercial energy consumption in the developing countries. Sectoral breakdown of oil consumption illustrates the unmistakebly important role played by this resource in the economy of the developing countries (UNCTAD, 1978), 91 per cent in transport, 66 per cent in domestic and commercial use and 48 per cent in industry. It is important to bear this fact in mind, for consideration of future consumption, patterns will be significantly affected by the availability and supply of oil at prices affordable by the developing countries. Alternative energy sources must be viewed in respect of how adequately they can substitute oil or oil based resources. Otherwise changes, sometimes major changes, in lifestyles will be necessary which in turn would inevitably call for longer time lag for any substitution.

In the rural areas where the bulk of the population still resides, non-commercial sources of energy (wood fuel, charcoal, animal waste eg. cow dung and plant waste) constitute the largest share. Data on consumption levels of non-commercial energy sources is scarce. But some effort has been from time to time to collect and standardize the data. Table 5, for example, shows energy wood fuel consumption by different regions of the world. It also shows the percentage of fuel wood and commercial energy to total energy (Arnold, 1979). It should be emphasized that the use of non-commercial energy is not confined to rural areas alone. Sizeable quantities are also consumed in the urban areas as Table 6 for selected countries clearly illustrates.

Table 4. End uses of commercial energy in selected countries[a/]

(Per cent)

	India (1970/71)	Mexico (1972)	USA (1972)	Fed. Rep. of Germany (1972)
Transport	32	39	35	20[b/]
Industry	39[c/]	43	29	36
Agriculture[d/]	5	1	4	5
Commerce[e/]	6[f/]	3	9	11
Residential	18	14	23	28
Total end uses	100	100	100	100

Source: UNCTAD, Energy Supplies for Developing Countries: Issues in the Transfer of Technology, (1978).

a/ Excludes non-energy use.
b/ Includes bunker.
c/ Includes mining.
d/ Includes mining and construction for all except India.
e/ Includes public uses.
f/ Includes construction.

Table 5. Fuelwood and roundwood consumption and fuelwood energy, 1974

Region	Fuelwood	Total roundwood	Fuelwood as per cent of roundwood	Energy[a] from fuelwood	Commercial energy	Fuelwood as per cent of fuelwood and commercial energy
	x 10^6 cu.m.	x 10^6 cu.m.	Per cent	x 10^{15} joules	x 10^{15} joules	Per cent
Developed Market Economies	54.9	790.6	6.9	531	140 449	0.4
North America	17.6	474.7	3.7	170	77 763	0.2
Western Europe	32.3	240.8	13.4	312	45 161	0.7
Oceania	2.5	21.5	11.6	25	2 654	0.9
Eastern Europe and the USSR	99.7	462.1	21.6	964	54 267	1.8
Total developed countries	154.6	1 252.7	12.3	1 495	194 716	0.8
Developing Market Economies	1 145.3	1 336.1	85.7	11 074	22 038	33.4
Africa	268.3	299.6	89.5	2 594	1 848	58.4
Latin America	243.9	298.0	81.8	2 358	9 383	20.1
Far East	577.0	667.9	86.4	5 579	7 577	42.4
Near East	56.1	70.6	79.4	543	3 230	14.4
Asian centrally planned economies	153.5	205.7	74.6	1 485	16 790	8.1
Total developing countries	1 298.8	1 541.8	84.2	12 559	38 828	24.4
World	1 453.4	2 794.5	52.0	14 054	233 544	5.7

x After Arnold (1979).

Table 6. Levels of household use of woodfuels in rural and urban areas in selected countries (cu.m./capita)[a]

	Gambia (1973)			Tanzania (1968/69)			Thailand (1970)		
	Fuel-wood	Char-coal	Total	Fuel-wood	Char-coal	Total	Fuel-wood	Char-coal	Total
Rural	1.20	0.12	1.32	2.16	0.02	2.18	0.76	0.51	1.27
Town	0.66	0.78	1.44	1.15	0.44	1.59	0.12	0.88	1.00
City	-	-	-	0.19	0.62	0.81	0.10	0.90	1.00

[a] charcoal expressed in terms of quantities of wood raw material.

Source: Arnold (1979).

FUTURE DEMAND

The demand for energy in the developing countries in the future cannot be predicted with any degree of certainty. For each country the demand will depend on a multiplicity of factors such as level of economic and industrial development and their rates of growth; population; income levels, availability of energy resources and comparative advantages of each of the other; trends in the price of alternative energy resources; policies for energy resources development; external factors such as action by major producers; world economic conditions; availability of financial resources. The list is by no means complete. Not a single one of these factors can be determined with any measure of certainty. Furthermore they interact with each other in a complete manner that has not yet been fully understood. Projections of future energy demand are appropriate at best. The situation in many developing countries is even more futile, aggravated by inadequate data required as a basis for estimate of future requirements.

The high degree of uncertainty accounts for conflicting projections for future energy requirements, globally, and in the developing countries as shown in Table 7. Each uses different assumptions. It should be stated that future energy requirements in the developing countries cannot be looked at in isolation. For events and actions in the rest of the world have a direct bearing on the patterns of future energy supply in the developing countries and vice versa. Thus policy actions in the developed countries in regard to aid, international trade, development of their indigenous energy sources, price for manufactured goods, transfer of all these will have direct or indirect impact on economic development policies adopted by the developing countries, on what patterns and nature of industrialization, on what energy technologies to acquire and on resources allocation between the energy sector on the one hand, and other sectors, which are also basic to national development, on the other hand.

Table 7. LDC Commercial Energy Consumption
(in millions of barrels per day of oil)

Country Category / Source of Projection	1975	1985	2000
OPEC			
WAES[3]	1.7	18.5 - 23.5	8.4 - 13.10
Non-OPEC LDCs			
BNL[1]	9.1		25.9
YER[2]			28.4 - 41.0
WAES[3]		14.9 - 18.2	26.5 - 35.6
Strout[4]			38.7
All LDCs			
WAES[3]	9.5	19.10- 23.10	34.9 - 48.7
CDC[2]		18.5 - 23.5	41.1 - 63.6

Source: Howe (1979).

The impact on energy consumption and economic development in the development in the developing countries of events and decisions on energy supply and price levels, taken in the developing countries has been amply demonstrated since a series of actions by the OPEC countries. The situation is the more complicated by the fact that decisions and actions by or within the developing countries have influence, sometimes, decisive, as has certainly been the case, since 1973 with the share rise in the price of crude petroleum. This together with spiraling inflation, increased price of imported food, other raw materials and imported manufactured goods have dealt a blow to the development prospects of many developing countries. Economic development has slowed down, unemployment has grown with leaps and bounds and above all their balance of payments has been adversely affected.

Now back to future demand, there are however certain observable long-term trends that may be a useful basis for estimating future energy requirements. Global energy demand has increased more than seventy-fold in slightly over one hundred years, rising from 0.1×10^{12} watts in 1860 to about 7.5×10^{12} in 1975 (Rotly, 1979). Three points are worth noting: first, that except for breaks during the two World Wars and during the depression of the 1930's, the growth in global energy consumption has been exponential. Second, the slope of energy consumption has been nearly the same for each segment of the broken line. Third, global rate of consumption has been constant at 5.3 per cent per annum since the end of World War II.

With the above factors in mind, taking 1975 as base (given in Table 8), Rotty has projected future energy requirements for the world and by regions. The results are reproduced in Table 9. While these figures are taken as the basis for discussing future energy availability, it should be noted that an inadequate allowance has been made for the shift in energy consumption in the developing countries, from traditional to commercial sources of energy. With anticipated increase in economic development and higher incrue levels, associated with migration from rural to urban areas, with increased commercial energy usage per capita, growth rates in energy. Consumption in the developing countries will be higher than those given in the table.

Energy Resources Base

The question that immediately comes to mind is whether there will be in the future sufficient energy resources to meet the ever growing demand. This question has occupied the minds of many particularly so in the wake of the events of early 1970's. The publication in 1972 of the Club of Rome's Limits to Growth generated heated discussions on the rate of depletion of a number of finite resources including energy.

The sudden sharp rise in the price of crude petroleum in 1973 accompanied briefly by interuption in supply brought to the fore not only the important role that energy plays in national economic development and well-being, but also heightened the interest in debate on future availability of petroleum and natural gas in adequate quantities to meet the ever increasing for these, and other, energy resources.

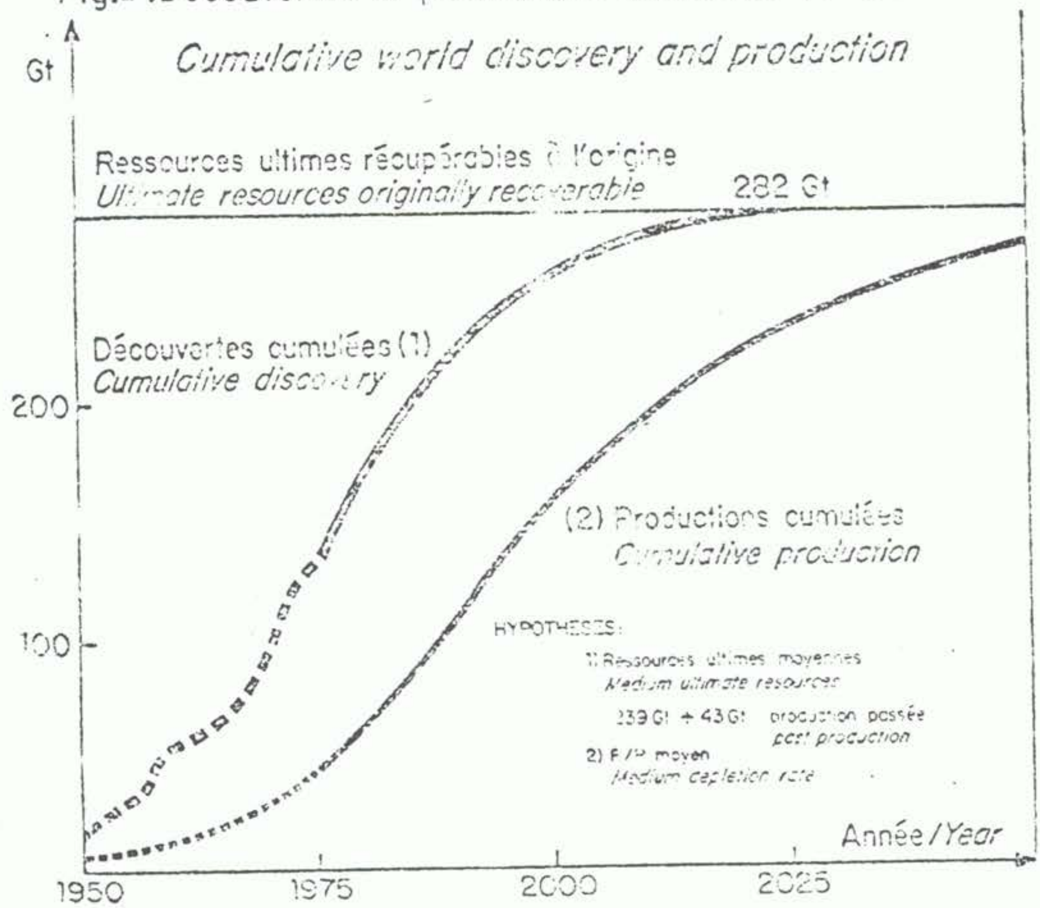
Table 8. World Energy Patterns - 1975

	Per Capita Energy (KW/cap)	Population in 10^6	Total Energy (TW)
N. America	10.13	237	2.40
W. Europe	3.74	365	1.37
USSR + CTP Europe	4.69	363	1.70
Japan, Australia	3.39	161	0.55
Dev. America	0.93	323	0.30
Dev. Africa	0.17	370	0.06
Dev. Asia	0.21	1,176	0.25
Dev. Mid-East	0.97	116	0.11
CTP Asia	0.65	885	0.57
World Total (average)	1.83	3,996	7.32

Source: Rotty (1979).

With regard to petroleum and natural gas, many estimates have been made first on the level of reserves and resources, and on the rate of discovery, on the one hand, and production on the other hand. The World Energy Conference (1978) has for example estimated that on the basis of information currently available there are adequate petroleum and natural gas resources to meet projected requirements well into the new century. Cumulative production and discovery rates for petroleum are given in Figure 2.

Fig.2 .Découvertes et productions mondiales cumulées



Source: World Energy Reserves 1985-2020, World Energy Conference, Ref.8.

Table 9. World Energy Patterns - 2025

	Per Capita Energy (KW/cap)	Population in 10^6	Total Energy (TW)
N. America	10.6	315	3.34
W. Europe	7.8	447	3.49
USSR + CTP Europe	10.1	480	4.85
Japan, Australia	7.6	320	2.43
Dev. America	5.2	797	4.14
Dev. Africa	1.2	885	1.06
Dev. Asia	1.2	2,665	3.20
Dev. Mid-East	5.2	353	1.84
CTP Asia	4.0	1,714	6.86
World Total (average)	3.91	7,976	31.2

Source: Rotty (1979).

Here again there are differing projections depending on the type of assumptions made. One area on which there is lack of consensus is the extent of reserves and resources available. The situation is further aggravated by the absence of universally agreed method of defining resources and reserves, thus making it difficult to undertake meaningful comparison*. There is also no agreed method of estimating future discovery rates as a function of exploration effort. Neither is it that clear just how accurately the future rates of production will be, for these to depend on future petroleum and natural gas price trends in relation to the price of alternative sources of energy, and on a host of other factors.

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In the following section we shall briefly present energy resources of the developing countries, both conventional and non-conventional, commercial and non-commercial. This should set the stage for ascertaining the adequacy of these resources to meet the future requirements. Conventional resources refer to hydraulic, coal, petroleum and natural gas, while non-conventional resources include, for the purposes of the present discussion, solar, wind, biomass, geothermal, oil shale and tar sands, tidal and wave energy and ocean thermal energy. Non-commercial energy refers to wood fuel, charcoal, plant and animal waste. In addition to presenting the resource base we shall attempt to highlight specific areas that need further research and development effort in order to ensure increased production and more efficient use.

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* There is a strong move to standardise the definitions of resources. Currently the most used definitions are "proved", "probable" and "possible" resources; other uses such as recoverable and ultimate resources are also widespread.

Coal Resources

Current estimates of known world resources of solid fossil fuels now total 10.8×10^{12} tons. The current survey also shows that of these 1.4×10^{12} tons are now considered to be recoverable under conditions of present technology and prices; of this about four per cent have been cummulatively produced. The bulk of the discovered coal resources exists in principally three countries - the USSR, the United States, and the Peoples' Republic of China - which together account for nearly 90 per cent of world resources; each of these nations has total geological resources of more than 100×10^9 tons(CNRET, 1978). More than half the world's remaining resources are in Europe, and the small remainder is in Africa, Latin America, Oceania, and the rest of Asia, particularly in Canada, India, South Africa, and Australia.

Estimates indicate that recoverable resources of coal in developing countries constitutes a very small share of the world reserves of mineable solid fuels, (estimate 10.6 per cent). The total recoverable resources of developing countries are estimated at $27,339 \times 10^6$; of these, about one per cent had been cummulatively produced by 1974. Of the total estimated coal resources of developing countries, $16,224 \times 10^6$ or 59.3 per cent were in Asia; Latin America accounted for $6,695 \times 10^6$ or 24.5 per cent, while Africa had $4,420 \times 10^6$ or only 16.2 per cent.

A review of primary energy production in developing countries shows that there was a marked decrease in the output of coal during the period 1950-1974 measured in terms of total primary energy output. While in 1950 the production of solid fuels in developing countries represented a share 104.1 per cent of their primary energy production, by 1960 the share had further declined to 5.3 per cent, or approximately a two-fold decrease in coal output. Although in absolute terms coal output in developing countries rose nearly two and one half-fold between 1950-1974, the share of coal output was relatively small in 1974, representing only 4.7 per cent the total primary energy production.

In most developing countries comprehensive surveys have yet to be undertaken. This is an area that requires urgent attention. More systematic and comprehensive surveys could lead to the discovery of more coal reserves. More systematic and comprehensive surveys are required. This should take advantage in recent developments in exploration technologies including more advanced geophysical and drilling techniques. All this should lead to up-dated inventory in the developing countries and thus pave the way for their development and utilization.

Coal transportation, from the mine mouth to the point of use is in general a costly undertaking, one which may limit increased use of coal in developing countries. For countries with adequate network of railways and waterways, this may not pose a major problem; further transportation cost reductions could be achieved through improved transport approached e.g. increased density or utilization. For countries with large quantities of undeveloped coal reserves, special feasibility studies will have to be undertaken to determine the best mode of transportation, chosen from railways, waterways including canals or pipelines.

For those countries with large coal deposits, there is a strong case for embarking on increased production and utilization of this resource, necessitating the development of cheaper and more efficient methods of coal mining. It also requires a concerted effort to enlarge existing institutions and enterprises - institutional building or strengthening that incorporates timely training of technical and managerial manpower to operate and run the systems.

Coal mining hasalong history during which substantial advances in mining techniques have been used; there is nonetheless still need for improvement in this area for example the drilling of shafts could be improved. Solution to the problem of continuous removal of rock material during mining should be welcomed.

In mines relatively near the surface room and pillar methods are widely used; there is room for improving the method of leaving natural pillars of coal to support the most. The need to improve health and safety and working conditions cannot be over-emphasized. The main dangers include coal dust, explosives and fire from methane, gas escapes and carbon monoxide. Early warning systems, safety precautions etc. must be improved. Increased attention to coal mining will necessitate mining to depths deeper than 1200 m, which in turn requires better drills and mining techniques better support systems, cheaper ventilation systems.

Petroleum and Natural Gas Resources

Estimates of crude petroleum reserves are at 5989×10^9 barrels. While those for natural gas are of the order of 72×10^{12} m^3 the computation of total resource values depends upon certain methods of extrapolation from existing data; complete agreement on the most appropriate techniques of estimating data for a region is inherently difficult. Furthermore, the data is continually augmented by advancements in exploratory and recovery techniques.

In Africa abundant reserves occur in northern Africa in Algeria, Libya and Tunisia while smaller reserves are to be found in Egypt. These countries together account for about 12 per cent of the known world and 84% of Africa's reserves of crude oil; natural gas reserves are respectively about 7.6% and 70%. New discoveries in recent years have more than doubled the known recoverable oil reserves of northern Africa. Coastal areas and the continental shelf of middle and western Africa have reserves of crude oil and natural gas that are relatively recent in development. The region comprising Nigeria, Gabon, Angola contains about one-sixth of the continent's known oil and about one-fourth of the gas reserves. Annual crude oil production from Nigeria is in fact currently second only to that of Libya on the African continent.

Africa ranks second to Asia in known recoverable reserves of crude oil and fourth in known recoverable of natural gas. The continent has about 14% of the world's crude oil and 11% of its natural gas.

Crude oil and natural gas deposits are found in a number of locations in Asia, with most abundant deposits in the oil-rich Persian Gulf area. This region is currently supplying over 40% of the world's requirements of crude oil. When oil production from the remainder of Asia is included, the continent's fraction of world production is about 43%. Proved recoverable reserves of crude oil and natural gas in the Persian Gulf region are approximately 55% and 10% respectively, of the world total. Substantial reserves of natural gas also exist in this region. During the decade 1961-1970, the Persian Gulf fields furnished about 28% of the world's crude oil requirements. Natural gas production in 1975 was about 10% of world production with Iran accounting for over one-third of the regional output. Lack of pipeline or cryogenic transport facilities to major markets however restrains widescale production gas in Southwest Asia.

Latin America has large crude oil and natural gas deposits and is a major producer. Venezuela has the largest oil and gas reserves on the continent with estimated proved recoverable reserves of crude oil and natural gas of about 80% and 52% respectively.

Hydraulic Resources

Hydraulic resources in the developing countries represent two-thirds of the world's total only a small fraction of which have been exploited to date: less than 5%; thus it is readily apparent that some of the greatest opportunities for the developing countries lie in the development and utilization of the largely untapped hydraulic resources. On a global basis developing countries currently account for 20% of world hydraulic energy output.

About 22% of all hydraulic resources are in Africa. Africa, however, produces only 30,000 gigawatt-hours/year or 2.3% of the world's hydroelectric energy production. These resources are, however, not evenly distributed, with the largest generating sites to be found in Egypt, Ghana, Rhodesia or Zambia, Mozambique, Nigeria and Zaire.

The hydraulic resources of Asia, excluding the USSR and Japan, have a capacity of 685,000 megawatts with an approximate annual output of 2.6 million gigawatt-hours. The bulk of these resources are in the rivers draining the Tibetan Plateau giving the following approximate distribution for Asian resources : The People's Republic of China 50%, India 10%, Burma 8%, Indonesia 6% and Pakistan 4%. Most of the remaining resources are in North Vietnam, Laos and Turkey.

Total annual hydraulic resources of Latin America is 1,850,000 gigawatt-hour about 19% of the world total. About 70% of these resources are in tropical South America, 18% in temperate South America, 11% in Mexico and Central America, and less than 1% in the Caribbean nations. Total production in Latin America is 110,000 gigawatt-hours/year, about 8.5% of world output of which 53% is from Brazil. Nearly all of the large rivers in Latin America are in tropical South America.

Oil shale

Oil shale refers to certain fine-grained sedimentary rocks from which oil can be obtained by solvents or by heating the rock to temperatures ranging from 350°C to 1,000 C. The organic matter in oil shales is almost completely insoluble and with current technology less than 5 per cent can be extracted. The mineral content of oil shales can be composed of sand, claym or lime, or a mixture of these. In some cases, the oil shales contain appreciable quantities of natural alkali minerals.

The occurance of oil shale is widely distributed geographically throughout the globe including many developing countries. The oil, produced by heating (retorting) the shale varies to some extent depending on the nature of the deposit from which it is produced, and the type of distillation process employed. Shale oil contains nitrogen compounds as well as sulphur, and the hydrocarbons have a different chemical structure to those of crude petroleum. By a refining process, which usually involves the addition of hydrogen, the raw shale oil can however be upgraded to make a fairly good quality synthetic crude oil, which can be processed in the same manner as crude petroleum of comparable quality.

Raw shale oil is characterized by a relatively high specific gravity (around 0.95), and a high wax content. In practice, the quality of the products can be varied by changing the retorting temperature. If retorting of the shale is carried out at a sufficiently high temperature, only gas is produced with no liquid petroleum fraction.

Tar Sands and Reserves

Tar sands and similar bitumen impregnated rocks are of widespread occurence; but their exploitation as a source of fuel is limited at the present time to one plant in western Canada. In addition to the tar sands actually exposed at the surface, there are vast reserves or heavy oil known to exist in various areas of the world.

Tar sands and similar deposits of potential importance are known to exist in Western Canada and the United States of America, Venezuela, Ecuador, West Africa, Madagascar, and in several other countries. Estimates of world reserves of producible oil in these deposits are as high as 621,000 tons of coal equivalent nearly twice the level of estimated world petroleum reserves.

A commercial plant of 45,000 barrels per day (8,000 tons of coal equivalent per day) has been in operation since 1968 at the Athabasca tar sands of Alberta, Canada. Recent reports indicate that additional plants will be constructed in the same area in the near future. The slow development of tar sands for oil extraction in the past may be attributed to technological factors as well as to the generally declining prices of crude oil of the past two decades. With the recent increases in oil prices, coupled with advances in the technologies for oil extraction from tar sands, utilization of tar sands as an energy source is expected to increase in the future. In this context more attention should be given to the development of tar sands, culminating in the building and operating more commercial plants, in the developed as well as developing countries.

Geothermal Energy Resources

These are a set of energy sources derived from the hot internal core of the earth accessible by drilling; natural manifestations include volcanoes, geysers, fumeroles, hot springs, etc., while the sources harnessed by man include steam wells and hot water wells.

Quantitative reserve estimates of any sub-surface resource such as geothermal resources inevitably contain a large element of uncertainity, the more so for geothermal energy which is a relatively new field. Reserve estimates for deep, low-grade geothermal resources are more reliable because many more wells have been drilled in sedimentary basins, in the course of search for oil, than mountainous, volcanic terrain, which is the typical domain of high-grade geothermal resources. Further research and development is required in order to ascertain the nature of distribution of high temperature corrective systems and thus improve geothermal reserve estimates. Further work is also required for better determination of recharge characteristics of shallow geothermal resources systems. Production characteristics of volcanic rock, which will probably contain the majority of shallow high temperature systems, are very poorly known; this area too is in need of concerted research and development effort.

High grade geothermal resources are likely to occur in those regions characterized by active volcanism. The most coherent of these zones is the chain of volcanism which occurs along the eastern edge of the Pacific Ocean extending from the Aleution Islands through Alaska, western North America and including all the countries in Central America as well as the Andean countries of South America. Three of the world's producing geothermal fields are located in this zone and new fields have been discovered recently in Nicaragua and Chile. High temperature resources may exist on the volcanic islands of the eastern carribean; high temperature reservoirs have been identified by drilling in both Guadalupe and St. Lucia. The Western Pacific is also a major volcanic province including the Kamchatka Peninsula, and theisland are segments of Kruil, Japan, Ryukyu, Taiwan, the Philippines, Indonesia, New Guinea, the Solomon Islands, New Hebrides, Fiji, Tonga, Somoa, New Zealand, and the Hawaiian Islands. Four of the world's producing geothermal fields are located in this region.

<u>Wave Energy</u>

Wave energy is derived indirectly from solar energy; waves are generated by wind, which is in turn derived from solar energy. Total wave energy has been estimated to be of the order of 27.3×10^6 tonnes of coal equivalent - nearly three times the current world energy consumption.

But technical and economic feasibility of harnessing wave energy is still far off in the horizon. Interest in the design of systems to generate energy (electricity) from wave is growing and concerted research and development effort is reported from Britain and Japan. This should pave the way for more widespread research and development effort that should eventually lead to widescale utilisation of this abundant resource, especially in geographically favourable locations in the coastal areas.

It should be noted however that available wave energy varies greatly over the year, thus necessitating the installation of back-up systems.

<u>Tidal Energy</u>

Tidal energy is generated by the interaction of the earth's rotational force, and the gravitational pull of the moon and sun. Tides thus rise and fall every 24 hours and 50 minutes - approximately the period of rotation of the moon. This time factor precludes the occurence of the maximum water level at the same time on consecutive days, a point that must be taken into account in the design for harnessing tidal energy systems. In addition, tidal amptitude varies from day to day.

The maximum amptitude by the topography of the coast. Under favourable conditions these can induce resonance thereby accentuating tidal amptitude. Amptitudes of as high as 15 meters in such locations are not uncommon, in the open sea tidal amptitude are normally of the order of one metre.

Tidal energy potential is of the order of only 3 TW. While globally this may be insignificant, in the locations where conditions are favourable, availability of tidal energy can make a significant difference. The limiting factors would seem to be the economics of construction and installation of tidal energy systems.

Energy consumption has been growing steadily over the last 25 or so years; energy consumption has more than trebled.

RESEARCH AND DEVELOPMENT REQUIREMENTS

In this sectionm a summary reviewing Research and Development (R+D) requirements for the exploration and development and use of conventional sources of energy is given. The summary is by no means exhaustive. Note also that the requirements are not specific to developing countries. Energy issues are global and, as noted, a global perspective is desirable. In any case, much of the research and development has, and will continue to take place, largely in the industrialized countries. Many of these technologies will find their way intact in the developing countries. Others may require modifications here and there in order to suit conditions obtaining in the developing countries. The point of emphasis is that concerted R+D should add to better exploration approaches, increased discovery rates, improved production procedures, more efficient concession processes and better distribution as well as more efficient end of energy resources. All these should, in effect, lead to increased reserves to meet future energy requirements.

(a) Oil

(i) Exploration and drilling

After more than a century of oil exploration many large sedimentary onshore areas of the world remain unexplored. In this respect, it may be sufficient to point out that even in the United States where exploration has been most intensive billions of barrels of oil remain to be discovered. Recent studies submitted to the Committee on Natural Resources and the United Nations Intergovernmental Group of Experts on Mineral and Energy Exploration have indicated that the petroleum potential of the developing world, including a great number of oil-importing developing countries has hardly been touched upon.

One of the basic problems relates to the risk involved in exploration. There is still need for more geological, geophysical and geochemical research to ensure better understanding of geological formations to enhance the use of more advanced scientific techniques and instruments, thereby assuring a reduction of the margin of error in oil exploration. There is also need for investigation of methods that could ensure direct detection of sub-surface oil or gas; furthermore, there is need for better seismic data interpretation techniques which could distinguish between seismic echoes from rocks on the one hand and liquid gas on the other.

The application of air craft and space craft remote sensing techniques and technology holds promise. It should lead to better understanding of the sedimentary basin systems where oil could be found. Further research and development relating to photographic and other equipment and data interpretation is required.

Exploration would involve inter alia drilling especially so in order to obtain more accurate assessment of the extent of the discovery. Drilling is a very expensive undertaking; there is therefore need to undertake improvements such as faster drilling speeds and increased depth. New methods such as high speed jet drilling, in which holes are bored without mechanical contact are currently under intensive investigation and appear promising. More effort is, however, required in this area. Furthermore, there is need for continuous interpretation of core samples, obtained in the course of drilling, in order to improve the judgement of drillers before they strike oil. More research and development is required to help drillers understand, not only where to drill, but also when to continue drilling on the basis of analyses of core samples.

(ii) Secondary and Enhanced Recovery Methods

Once drilling has been undertaken, and the existence of adequate resources established, production of these resources follow. In many instances the petroleum resources have to be pumped from great depths. There is thus the need for improved pumping technologies that are more efficient and compact.

Major technical advances in secondary and tertiary oil recovery have been witnessed over the past two decades. Mention should be made of research and development currently under way on advanced techniques using steam heat and chemicals. Additional research and development is also required in order to provide a more precise knowledge of how oil and water are attached so that more effective recovery techniques can be devised. In applying recovery techniques the tendency has been to recover oil by conventional methods up to the limit - of about 30 per cent recovery - and then to apply secondary recovery techniques followed ultimately by the application of tertiary recovery techniques. It is, however, now becoming apparent that increased recovery is possible when secondary and tertiary recovery methods are used from the very beginning. Further research and development effort is required in this area in order to prove the viability of such approach.

Some experts have indicated that recovery factors could be improved to as much as 60 per cent of the oil in place. For example, recent studies in the United States on enhanced recovery indicate that this now yields about 300,000 b/d and could increase oil production by 3,000,000 b/d by 1995. Such an improvement would double oil reserves. In addition to conventional oil resources, vast deposits of heavy oils are known to exist in various countries. One of the best known deposits is that of Orinoco in Venezuela where resources are estimated at about 100 billion tons which is equivalent to all the proved conventional oil reserves of the world today. The Government of Venezuela is undertaking a considerable research and development effort to improve recovery from these deposits and co-operation agreements have been reached with other countries (e.g. Canada). Fundamentally enhanced recovery will be aided by the application of improved secondary and tertiary recovery methods. It may be indicated that even a 10 per cent recovery factor would translate into 10 billion tons of oil, which is about 6-7 times the proved reserves of conventional oil of Venezuela.

(iii) Offshore Oil

Offshore exploration and development present very special demands, which require further research and development effort. The major offshore activities are geophysical prospection; drilling; well-head completion; production and transfer of crude petroleum to shore. In generalm offshore drilling and production present more technical headaches and are more expensive than onshore ones. Drilling techniques vary according to prevailing geological and environmental conditions in the area and to the ocean depth. In very shallow waters artificial islands can be built; for deeper water anchored semi-submersible or jack-up rigs floated on location or positioned from huge platforms can be used.

For depths beyond 200 metres dynamically positioned mobile rigs can be used. Much, however, remains to be done in the form of development of systems that could be used for drilling of depths of up to 1000 metres and beyond. Oil from ocean bottom presents different technical problems from those of onshore activities. Here again, research and development can play a crucial role in the development of more flexible and efficient production methods.

(b) Natural Gas

In addition to the problems commonly shared with oil, natural gas faces certain unique research and development problems. One relates to the storage and transport of natural gas. In fields where gas is associated with oil the flow of gas cannot be controlled. Gas which is not used may be reinjected, liquefied or flared. Reinjection may help maintain the pressure in the oil wells and thus preserves the gas for future use. There is, however, a limit to which reinjection can be undertaken. Consequently, in many areas, notably the Middle East, most of the gas associated with oil is flared. A possible solution is to convert the gas into fuel which can be easily stored and transported.

Transportation of natural gas is an area which requires research and development activity. The two methods in current use are the pipeline or the tanker; in the latter the gas is liquefied for transport overseas. The liquefied form of transport requires special expensive ships. Further research and development effort in this area is required in order to develop simpler liquefaction, transportation, storage, techniques that are less prone to accident. Another area deserving more research and development work is the feasibility of converting natural gas to methanol which can be transported. This route is currently very expensive. It, however, holds some advantages: methanol could be cost competitive with LNG long-distance transportation. More work is required to establish commercial usability of methanol.

Offshore gas raises a number of specific problems that have to be overcome - including the development of cheap reliable on-platform liquefaction and methanol conversion technologies.

(c) Coal

Comprehensive surveys have yet to be undertaken in most developing countries. This is an area that requires urgent attention. More systematic and comprehensive surveys could lead to the discovery of more coal reserves. This should take advantage of recent developments in exploration technologies including more advanced geophysical and drilling techniques. All this should lead to updated inventory in the developing countries and thus pave the way for their development and utilization.

Coal transportation, from the mine mouth to the point of use is in general a costly undertaking, one which may limit increased use of coal in developing countries. For countries with adequate network of railways and waterways, this may not pose a major problem; further transportation cost reductions could be achieved through improved transport planning and management e.g. increased density or utilization. For countries with large quantities of undeveloped coal reserves, special feasibility studies will have to be undertaken to determine the best mode of transportation, chosen from railways, waterways including canals or pipelines.

For countries with large coal depostis, there is a strong case for embarking on increased production and utilization of this resource, necessitating the development of cheaper and more efficient methods of coal mining. There is also an urgent need for a concerted effort to enlarge existing institutions and enterprises.

There is need for improvement in mining techniques; for example in the drilling of shafts; or in regard to the problem of continuous removal of rock material during mining. In mines relatively near the surface room and pillar methods are widely used; there is room for improving the method of employing natural pillars of coal to support the roof. For deep mines (more than 1200 m.) better drills and mining techniques, better support systems, cheaper ventilation systems will be required.

Except in large installations such as power stations, coal is not the ideal fuel both because it is not fluid and because it usually burns less cleanly than either oil or gas. Success in exploiting coal reserves, therefore, partly depends on the development of a technology that will convert coal into oil and gas on a large scale. The principles of the technology already exist, as do a number of pilot and demonstration plants where the conversion is being accomplished on a small scale. The problem, then, is to mobilize the financial, industrial and research and development resources that are needed to put the technology on a commercial basis.

(d) Hydraulic Resources

Assessment of hydraulic resources involves seasonal measurements of rainfall, particularly in the higher regions of river basins, and of river flows at many locations, especially at those sites with suitable topography for hydroelectric installations. Frequent measurements over many years to obtain average annual rainfall and flows is highly desirable. Data on subsurface hydrology may also have a major bearing on resources since the bulk of natural fresh water is subterranean. In addition, in arid regions temperature and humidity measurements may be significant because the water loss from large reservoirs may represent some reduction in water availability for hydropower production. Finally, topographically suitable sites must be examined geologically to determine the suitability of local earth and rock for dam foundations, tunnels and sluiceways. Better and improved methods of determining subsurface hydrology requires further research, as does the development of quicker and cheaper methods of examining geological conditions in aid of the assessment of hydraulic resources.

Such activities are particularly called for in the developing countries where most of the hydropower potential of the world remains to be developed.

(e) New and Non-Conventional Energy Sources

There is need to appraise the potential and feasibility for the utilization of non-conventional sources of energy. This should involve collection, analysis and assemblage of information on current techno-economic development and applicability of energy sources such as solar, wind, biomass, geothermal, tidal, ocean wave and ocean thermal sources of energy.

Solar Energy

Solar energy systems cover a wide range of specific energy source, including solar thermal systems, photochemical systems, biomass systems, aeolian systems and hydrological systems. The potential for application of solar thermal energy to meet certain categories of energy requirements such as water distillation, water heating, drying, cooking and, to a limited extent, refrigeration, and air conditioning - in urban areas as well as, but mainly in rural areas - is already apparent. Many problems have, however, to be overcome before solar energy can attain widespread application.

Solar distillation may refer to simple basin-type solar stills on the one hand and solar assisted distillation on the other hand. The technology of water stills is simple. However, further research effort is required in order to extend the capacity of solar or solar assisted stills, to develop solar collectors that are resistant to sea water and to reduce production costs. Further research and development effort is also required in developing countries to cover the following: testing of construction material for solar stills, investigation of effect of coupling solar collectors to sea-water distillation equipment, investigation of problems of heat storage and transient behaviour of distillation plants.

Solar cooking technologies with varying degrees of effectiveness have been developed. Further research and development effort should concentrate on economic and socio-cultural factors bearing on widespread use of solar cookers; to date, such solar cookers as have been developed are expensive, a restraining factor, particularly so for use by rural poor, which constitutes a large part of the population in the developing countries.

Controlled solar drying has gained increased interest and there is good potential for application of such techniques. Examples of potential applications are fruit-drying, fish-drying and the drying of general agricultural produce. Additional research, development and demonstration work are required.

Technologies for solar refrigeration and air-conditioning are less developed. Only a small number of prototypes have been developed to date, especially for modified absorption systems. Ammonia water has been found suitable for ice production. Further research and development is required especially on solid refrigerants.

Photovoltaic cells represent the most developed solar energy source. They have been applied to terrestrial uses needing very small power supplies which would be equally costly if produced from any alternative source. Development programmes are in hand in several countries to mechanize and increase the production of silicon semiconductor material; to develop other semi-conductor materials; and to operate cells in radiation intensities much higher than that of unconcentrated sunlight. These programmes will probably reduce capital costs of photovoltaic cells.

Wind Energy

Although wind has been harnessed for many centuries, its use has been limited in comparison to other forms of energy due to its fitful availability, and the impossibility of storing the energy cheaply. Furthermore, because of the low density of the air in some locations, small-capacity windmills of wind speeds is not conductive to the desirable constancy of the voltage and frequency.

The problem of matching load to random availability of wind power can be partially solved, especially in less isolated areas, by a parallel operation with a thermal or hydroelectric plant, which can then pick up or shed load so as to adjust to the difference between load demand and the contribution from wind power. In this manner savings in the use of fuel can be achieved.

For isolated plants, the problem of load matching may be reduced by the introduction of some means of energy storage. One such scheme that offers promise is to use the variable power output of wind to decompose water into hydrogen and oxygen; these would be stored under pressure and recombined in a fuel cell to generate electricity on a steady basis. Alternatively, the hydrogen could be burned in a gas turbine; which would turn into a conventional generator. Alternatively, the hydrogen could be burned in a gas turbine; which would turn into a conventional generator. Alternatively, for isolated plants, wind plants may be limited to supplying loads that are not restricted to the time of incidence.

In order to make estimates of potential wind energy available on national or regional level, reliable meteorological data, in particular those related to wind-speed are needed. Studies of special interest include analyses of frequency of occurence of low windspeeds.

An important consideration in the preparation of a design for wind energy system on a large scale regards the optimum way for the spacing and relative location of individual generators within a group of wind generators. It may be necessary to employ modelling techniques related to the boundry layer of the atmosphere as an aid to the evaluation of wind production capabilities of envisaged systems. Of special interest in this context is the need to develop models describing wind speeds and directions at locations and heights other than the selected stations from which routinely collected data are available.

In order to be able to utilize wind energy as part of a large scale energy production system, wind forecasting techniques applicable to winds at heights between 50 and 200 meters should be developed. A high degree of predictability at relevant heights, i.e. accurate forecasts of wind energy production in relevant time scales, will improve the potential of using wind energy as part of a national or regional energy production system.

There is need for improved measurement techniques in the field of atmospheric science in connexion with wind energy prospective, site selection and wind energy production. Of special interest are techniques based on remote sensing from the surface and from platforms, including satellites.

In order to facilitate wind energy conversion system designs, standards for the special measurements and presentation of data for this purpose have to be developed. Such standards have to be decided in close co-operation between wind energy system designers and atmospheric scientists.

Several wind energy conversion units based on various aerodynamic or electrical design criteria or combinations thereof are being built or planned. In order to facilitate a reliable evaluation of the potentials for wind energy production, an integrated analysis should be made, incorporating all relevant factors involved - such as, wind characteristics of the wind energy conversion units as well as the features of the entire electric energy production system.

Reports on studies of the wind energy potentials have been presented from a number of industrialized countries. Estimates of available wind energy have primarily been made on the basis of wind statistics produced from measurements at the routinely operated meteorological stations and in some cases complemented with data from short-term measurement campaigns showing the wind variation with time and space in a specific region.

The results so far confirm that available wind energy per unit land area is highly variable with geography and topography and also with time. The highest potentials for wind energy should be in the mid-latitudes of both hemispheres and north respectively south of approximately 45 and in the trade wind belts. Ocean and coastal areas should have higher potential than continental areas although high potentials may be found in certain plain and mountainous areas depending on surface roughness and atmospheric stability conditions. In mid- and high latitudes the potentials should in general be greater during the winter than during the summer.

Estimates of the cost of wind energy relative to other forms of energy have been made. The estimates are generally based on present technology, under certain specified conditions and do not normally include consideration of all factors involved. Available data and information are not sufficient for a complete cost-benefit analysis.

Biogas

Biogas holds considerable promise for the developing countries. Biogas digester can be made of relatively simple construction using indigenous material. However, the experience to date shows that capital costs of a digester are still quite high and beyond the reach of an average rural inhabitant of many developing countries. Moreover, the operating record of many prototype designs have been poor. Further work is required to improve digester design and reduce production costs. Further research and development effort is also required in order to better understand the fermentation process, including: a) the loading of new digesters for optimum operating conditions; b) optimum temperature conditions; c) the amount of stirring required without excessive aeration of the slurry; d) required urine in the feedstock; and e) the nature of bacteria that are involved at the first or second stage of fermentation. All of this would have to be done under different operating conditions using combinations of feedstock and in different areas of the developing world. It is also desirable to carry out further research and development work in the field of retention time of slurry in the digester and also to determine the best possible digester size and different operating conditions.

Geothermal Energy

Little or no exploration has been undertaken specifically for low-grade geothermal resources, which have been found for the most part as a by-product of petroleum exploration. Because of the lateral homogeneity of the conductive temperature gradients which form these resources, and the lateral uniformity of the sediments which contain them, exploration specifically undertaken for low-grade deposits does not have the high risk aspect of finding high-grade deposits. The need for increased exploration for deep low-grade geothermal resources cannot be overemphasized.

For many countries the most important application of geothermal energy is for power production. High temperature reservoirs are required for this purpose. In many developing countries, with relatively small electricity systems, the comparatively small size of geothermal power stations is better suited to their present scale of electricity supply systems in these countries. The exploitation of geothermal energy in these countries may therefore assume greater relative importance. At the present time, the utilization of geothermal resources is taking place mainly in developed countries, except for a limited number of cases in developing countries including El Salvador, Mexico and the Philippines. However, it can be anticipated that under the stimulus of current conditions in the international energy field, the transfer of appropriate technology and experience to developing countries will proceed on an urgent basis and will result in rapid progress.

The global availability of low-grade geothermal energy suitable for space heating as well as agricultural and industrial applications appears to be very large. The uses to which this energy can be put, however, are limited by the low-grade and non-transportability of the energy. Furthermore, the extent to which it will be used in any given country will depend very much on climatic conditions. For example, there will be little or no demand for domestic space heating and greenhouse heating in the tropical and sub-tropical zones where many of the developing countries are located. The use of low-grade heat for crop-drying and for food and industrial processing, however, should find wide application in developing countries. Indeed, developing countries are in an advantageous position with respect to using geothermal energy for industrial and food processing purposes because industries can be located from the start to take advantage of geothermal energy, where as in industrialized countries it may be prohibitively expensive to relocate established industries to achieve this same advantage.

Despite encouraging estimates of the resource potential, both low and high grade, geothermal development is progressing at a slow pace. A major reason is that deep drilling is expensive and the results of drilling uncertain. An expenditure of the order of 2 to 3 million dollars, invested over a period of about 5 years, is required to establish the presence, or absence, of a geothermal resource in any one project area. Finding this risk capital is a major obstacle for the development of geothermal energy in developing countries. It is difficult to obtain this initial investment for two reasons: firstly, the banks which are the normal source of investment in the power sector are unwilling to risk their capital on exploration ventures; secondly, private investors, the normal source of risk capital, are not particularly attracted to geothermal exploration. If obtaining the relatively modest amounts of risk capital required to find a geothermal field is difficult in developed market economies, the problem is magnified in the developing countries.

Developing countries can adopt a number of measures which would tend to conteract the problem of obtaining risk capital to initiate geothermal development. The first would be to promote co-operation among the various agencies concerned with geothermal development within a country in order to make maximum use of all the scarce resources available; the second would be to promote co-operation among countries in the same region, thereby achieving savings of both time and money by the sharing among countries of expertise, laboratory facilities, and expensive drilling equipment.

With reference to promoting co-operation within a country, it should be noted that a well organized and efficient geothermal project requires close co-operation of the national geological survey and the national energy authority. Energy authorities are the logical funding agencies, even for the initial exploration stage, because they generate revenue for capital investment and are the beneficiaries of the results of the project. The geological surveys, which have the expertise for exploration, seldom have funds to undertake work of this magnitude. Poor understanding of each other's problems, obligations, procedures and objectives, has marred the logic of the partners working together in co-operative effort to implement a well-organized and adequately funded project.

With reference to promoting co-operation among countries, a detailed examination should be made of the possibility of establishing regional centres in selected developing countries for the purpose of assisting participating countries on their exploration programme. Such centres could provide highly qualified experts to advise participating governments on the many aspects of geothermal technology; provide specialized field survey equipment to individual governments; provide exploration drilling equipment to be shared among governments; organize a laboratory to service the requirements of the region; organize and sponsor training programmes both within th e region and overseas.

Oil Shale

Shale has been mined and oil extracted from it using a variety of kilns, ranging from the batch retort, through semi-continuous and continuous process kilns; within this range are to be found vertical, inclined, rotating, stationary and fluidized bed kilns, and tunnel ovens. The technology of the production of oil from shale can be carried out in two distinct ways: a) mining followed by retorting in a surface plant, and b) the in-situ (below ground) method of oil production. Although in-situ oil production is still in the experimental stage, it promises high resource recovery and low environmental impact; and should receive increased research and development effort.

The conventional method of first mining and then retorting the shale in a separate plant is the one currently employed for all large-scale shale developments. Where feasible, open pit mining has been employed because of the lower costs involved. The bulk of the operations to date have, however, involved underground mining. Three above-ground methods of retorting mined shale have now been developed to a pilot plant stage. These include the rotary kiln process; the gas combustion process, using a vertical kiln with shale fed in from the top; and the vertical kiln process with shale pushed upwards from the bottom. Further development and demonstration is required in order to establish the viability of these processes under differing conditions - geographically and with regard to the quality of shale.

In-situ retorting processes are thermally inefficient and wasteful in terms of the percentage of the total reserve recovered. Nevertheless, such processes offer economic advantages because they avoid the heavy cost of mining the shale, transporting it to the processing plant, and disposing of the spent shale ash. Moreover, the processes are free of environmental constraints that have adversely affected the growth of shale oil industries.

The more advanced experimental plants are all of the continuous process type. Many variations on the basic retorting processes have been devised: some systems involve partial combustion of the shale with air while others heat the shale in a closed retort and use the gases evolved for heating purposes; still other systems employ indirect heating of the shale by contacting it with hot spent shale, or ceramic balls heated to a high temperature. Further research and development effort is required before the commercial viability of these methods can be established. For the developing countries that are well endowed with oil shale resources, there is need to develop or transfer technologies that are more suited to the techno-economic and social conditions obtaining there. For example, technologies that incorporate more intensive labour utilization, should be encouraged - as opposed to the development of labour saving technologies, which is the major concern of industrialized countries.

Requirements for large quantities of water seem to be a crucial factor in the development of oil shale on large-scale. Techniques have been developed that have so far involved extracting the shale and moving it into combustion, techniques which require considerable quantity of water and which in addition leave large quantitives of spent shale above the ground. It is estimated that approximately 3 barrels of water are needed to produce one barrel of shale oil. Where there are adequate quantities of water technologies currently available should be used to develop oil shale resources. Where availability of water is a limiting factor, more attention should be given to in-situ methods of production.

While large oil shale deposits are known to exist in many parts of the world, systematic exploration of these resources is still required in order to obtain their most accurate geographic distribution. There is for example need to prospect more extensively for shale formations are deeper than surface layers.

Small-Scale Hydraulic Energy Sources

Large-scale hydroelectric installations can be economically justified only when the site provides large hydraulic head and/or large flow rates. In addition to the larger waterfalls, there are a multitude of smaller ones in many developing countries. The development of small-scale machinery (micro-hydroelectric systems) that can economically be utilized to harness these local sources of energy requires serious attention and exploration. Some of the available technologies are discussed below. The following general remark can be made: further research and development effort followed by feasible prototypes is required in order to pave the way for more widespread application of this important energy source.

Hydraulic Turbine

Energy has for a long time been derived from waterwheels, the precursors of the water turbine. Waterwheels were initially used for such tasks such as grinding grain for flour and animal feed, raising water for irrigation and water supply, textile manufacture and metallurgical processing. As the demand for their use increased over the centuries, the simple waterwheels became larger. They were later displaced by the water turbine as an energy source. The latter, with a much smaller volume could generate much more power than the largest waterwheel, and could perform more adequately at high or low heads than waterwheels; furthermore they could operate at a greater number of revolutions per minute than the waterwheel, principally by virtue of smaller diameter.

However, with the development of large-scale hydro- and thermal-electric central generating stations and the extension of electric power lines to rural areas, the manufacture of small water turbines began to decline rapidly. In view of the current energy situation, interest in small-scale hydroelectric units should be expected especially for use in developing nations. These are units capable of generating 5 - 15 Kw at heads of 3 - 6m. It must be emphasized that these same apparatus can perform useful mechanical tasks directly in addition to electricity generation; it may be connected via belts or gears to grain mills, pumps, wood and metal-working machinery, and other machines of production.

For use with low water heads, the fixed-propeller type of turbine or the more familiar Francis type is more suitable than the more complicated types such as the Kaplan, which adjust themselves to the electrical load. Small hydroelectric generators are currently available from several manufacturers in industrialized countries. Because of the limited production of such small hydroelectric units, their cost per kilowatt is relatively high. Units capable of generating 10 kW cost more than $1,000/kW, the cost per kilowatt rising for smaller capacity units; these do not include the cost of other necessary parts of the system, such as the dam, the piping connection (penstock) between the dam and turbine, and the housing; with all this considered, the cost of electricity at the generator would be much higher. Significant cost reductions are likely to be achieved in developing countries through the construction of some propeller-type turbines from local materials including wood.

The propeller and the Francis turbines have been used for a long period of time and their technical feasibility well established. However, further advances in cheaper manufacturing methods and materials could significantly reduce their capital costs.

The Hydraulic Ram

The hydraulic ram, developed in the 18th century, is a simple pump operated solely by flowing water. It is an automated device that uses the energy in flowing water to pump part of that water to a height above that of the source; it can also be used to compress air for operating machinery. Manufactured hydraulic rams are currently available at costs ranging from $200 to about $3,000, depending on size.

Hydraulic rams can operate 24 hours a day for many months with no maintenance. No significant improvements are anticipated for the foreseeable future. Additional research and development are suggested for the adaptation of the hydraulic ram to air compression for use in reciprocating engines and turbines.

The Hydraulic Compressor (Trompe)

The trompe is simpler than the hydraulic ram. It has no moving parts, but utilizes hydraulic potential energy very effectively in the compression of air. This system, which would operate continuously day and night without attendance, could store energy in the form of compressed air that can be used to drive turbines and reciprocating engines that, in turn, can drive production machinery or electric generators.

It is suggested that large-scale studies of the trompe be undertaken to verify data available from the literature.

Fusion Energy

Fusion energy production by nuclear reactions of light elements could be an important renewable energy resource. Research and development effort has largely been concentrated on fusion reactors that will use the heavy hydrogen isotopes, deuterium and tritium and that will incorporate lithium in a breeding cycle to regenerate tritium. The fuel is, in principle, abundant and widespread. Deuterium is a naturally occuring component of water; moreover estimates of high-grade reserves of lithium should be sufficient to supply fusion reactors for a long time to come, at manageable extraction costs. By the time fusion reactors come into stream, it is expected that adequate safety mechanisms and procedures shall have been developed; apart from the tritium no radioactive elements are involved in the fuel cycle. Fusion reactors will produce a lower amount of radioactive byproducts with significant shorter half-lives than do fission reactors.

The development of fusion energy is however, still at an early experimental stage; in fact, the demonstration of scientific feasibility has not yet been achieved. Two basic conditions have to be satisfied in order to realize a fusion reaction: the fuel has to be heated to a high temperature, 50 - 500 million degrees, and the hot fuel (plasma) confined for times long enough, (from a fraction to many seconds), to produce useful quantities of energy. These conditions can, in principle, be fulfilled in two ways: by magnetic and inertial confinement. In both these directions, substantial progress has been made over the last few years; but a lot more still remains to be done.

Common to both lines is an improved understanding of basic phenomena occurring in the plasma, as a result of refined experimental and theoretical methods of remodelling and simulation. In magnetic confinement progress towards a thermonuclear plasma has been achieved with the Tokamak approach. Temperatures within a factor of 5 and confinement times within a factor of 60 of those required in an actual reactor have now been achieved. In inertial confinement progress has been made by the successful demonstration of laser-driven pellet compression; target heating and compression have also been achieved by relativistic electron beams.

The next generation of large machines now under design or construction is expected to accumulate enough information for a better understanding of plasma physics with thermonuclear parameters. In particular, conditions approaching those in a fusion power reactor are expected to be achieved in the laboratory.

While studies on future fusion reactor and their engineering problems taken to date (almost exclusive in industrialized countries) have served to define the main outlines of the problems, to identify possible solutions and to give assessments of the potential feasibility of practical fusion reactors; and these studies have laid the foundations of planning for development programes in engineering and technology to meet reactor requirements, further concerted research and development effort is required before fusion energy can become a practical proposition. The problems are not trivial and their solution may turn out to be as difficult as the understanding and control of the plasma physics.

Such research and development could be maximized through efficient world-wide co-operation and planning in this field. The fostering international co-operation in this field involving the exchange of scientific information and plans between countries and laboratories is currently underway. The international Fusion Research Council composed of leaders of national fusion programs, advises the International Atomic Energy Agency on its fusion activities. The opportunities for collaboration and review of national programs made possible by this Council are exemplary as well as invaluable.

REFERENCES

Arnold, J.E.M., "Wood Energy and Rural Communities", Natural Resources Forum, Vol. 3, No.3, April 1979.

Brashear, J.P., Kuuskraa, V.A., "The Potential and Economics of Enhanced Oil Recovery", Journal of Petroleum Technology, September 1978.

Howe, James W., "Energy Problems of Developing Countries: Implications for U.S. Policy".

McNitt, James, "Geothermal Energy in Transition", Natural Resources Forum, Vol. 2, No.1, October 1977.

Meadows, Dennis L., et al, "The Limits to Growth", Universe Books, New York, 1972.

National Academy of Sciences, "Energy and Rural Development - Renewable Resources and Alternative Technologies", 1976.

OECD, "Energy R. and D.", Paris, 1975.

Rotty, Ralph, M., "Growth in Global Energy Demand and Contribution of Alternative Supply Systems", Conference on Energy Alternatives, East-West Centre, Honolulu, Hawaii, January 8-13, 1979.

United Nations, "Recent Trends and Future Prospects (E/C.7/70); Paper submitted to the Fifth Session of the Committee on Natural Resources, 1975.

United Nations, "Report of the Secretary-General on Multilateral Development Assistance for the Exploration of Natural Resources" A/33/256, 1978.

UN/CNRET Draft Supplementary Chapter on Energy, February 1978.

UNCTAD Energy Supplies for Developing Countries: Issues in Transfer and Development of Technology, TD/B/C.6/31, 17 October 1978.

UNECA "The Role of Energy in the Development of Human Settlements in Africa", African Regional Conference on Human Settlements, Cairo, Egypt, 21-26 June 1975.

UN/ESCAP "Proceedings of the Expert Group on the Use of Solar and Wind Energy, 1976.

UNIDO, "Technology for Solar Energy Utilization", 1978.

United Nations World Energy Supplies, Series J, Nos. 19-20, New York.

Voss, A. "Waves, Currents, Tides - Problems and Prospects", Paper presented at Conference on Energy Alternatives East-West Centre, Honolulu, Hawaii, 8-13 January 1979.

World Energy Conference; "World Energy Resources 1985-2020; Executive Summaries", IPC Science and Technology Press, 1978.

SPECIAL APPLICATIONS OF SOLAR ENERGY FOR RURAL AREAS

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SUMMARY

Solar energy is one of the most praised renewable energy sources in developing countries of Asia, Latin America and Africa due to its undepletable and environmentally acceptable characteristics. There are several fields of special applications of solar energy in some of these countries. This paper approaches the general energy problem analytically and presents some case studies where solar energy is utilized to meet a part of the energy demand of solar-rich developing countries. This paper emphasises the research work of a rather unusual solar energy application work carried out in Turkey. In this research a "solar-trailer" was designed for providing the hot water requirements of the workers working and living in the rural areas by Ege University, (Turkey), and was constructed and tested by the Turkish Highway Department. The paper concludes that through such applications a part of the energy demand of the less developed countries could be met.

Energy has a direct and vital role in the social and economic development of the world. Peoples of the world started to face serious problems related to energy shortages because of the difficulties in energy production and the world's limited conventional (hydrocarbon based and hydro) energy reserves. There has been a growing concern and a better realization of this fact since the 1973 petroleum embargo. The impact of this so-called "oil crisis"* caused great injuries in the social and economic development of the developing countries. These countries need to have higher consumption rates of energy for their

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* We would prefer to use the world "predicament" instead of "crisis" since crisis means "the turning point in a disease, towards life or death" and "can and must be cured with a quick-fix remedy or all is lost"; whereas predicament means "an unpleasant, difficult or dangerous situation" as it exists and no quick-fix remedy or no one answer will help to solve the energy problem. If started wisely and if acted quickly, however, there is a great opportunity to overcome the "dangerous situation". In the process, there is a requirement for international cooperation and for some changes in the lifestyles of the peoples of the world.

growth. In order to understand the real energy situation of the world and/or of a country of the world, one needs to have the production and consumption figures obtained from different energy sources on the same basis. Table 1 gives the necessary conversions between different energy sources.

Table 1 : Energy Conversion Factors

Amount	Source	Heating Value	metric Ton Coal Equivalent (mTCE)
1 metric ton	Coal	7000 Kcal/kg	1.00
1 metric ton	Lignite	3000 Kcal/kg	0.43
1 metric ton	Petroleum	10500 Kcal/kg*	1.50
10^3 kwh	Electrical	2300 Kcal/kw-h**	0.33
1 metric ton	Wood	3000 Kcal/kg	0.43
1 metric ton	Plant and Animal Residues	2300 Kcal/kg	0.33

* The range of heating values of petroleum derivatives is 9000-12000 Kcal/kg. The value of 10500 Kcal/kg is used as an average value.

** Direct conversion factor from kw-h to Kcal is 860, i.e. 860 Kcal/kwh (0.125 TCE/10^3 kw-h). The value of 2300 Kcal/kw-h as used here is suggested to be more realistic than the direct conversion factor in comparing the electrical energy obtained by hydraulic, nuclear, geothermal, bio-gas and solar sources with the electrical energy obtained in modern thermal stations burning coal, fuel-oil or other conventional sources (3).

For total world energy consumption in metric Ton Coal Equivalent (TCE) the following equation could be developed by using the data given in reference (1):

$$\text{m-TCE}_i = 5231 \text{ EXP } ((0.05) \times_i) \quad \ldots\ldots (1)$$

where:

m-TCE - metric Ton Coal Equivalent at year "i"
x_i - time dependent variable
x_i = 0 for "i" representing year 1965
x_i = 11 " " " " 1976

Per capita energy consumption follows also an exponential equation and can be written as:

$$\text{KCE} = 1588 \text{ EXP } ((0.032) \times_i) \quad \ldots\ldots (2)$$

where:

KCE - Kg Coal Equivalent energy consumption at year "i"
x_i - the same as E q(1)

About 99 per cent of the world's demand for energy was met by fossil fuels at the beginning of the century, and about 80 per cent of the demand is met again by the fossil fuels at the present. In terms of energy units for the year 1977 about 152 x 10^{18} Joules of fossil energy was used. The total consumption for the same year was about 224 x 10^{18} Joules. It is speculated that with the present rate of consumption the fossil fuels would be depleted within the next century (2) and accordingly laws of demand and supply will keep on elevating their price ceilings for the foreseen future. Here it is important to note the fact that per capita energy consumption figures cannot be taken universally as it varies from 6500 kgCE in developed countries to less than 1000 KgCe in developing countries. Table 2 shows the variation in the per capita energy consumption in different nations of the world. As discussed in the literature, there is a rather consistent relationship between Gross National Product per capita and per capita energy consumption (5,6). A Philippine model reflecting the relationship was tested for several developing countries and produced very satisfactory results (7). This model can be written as :

$$\text{m-TCE} = AY^aP^b$$
$$\text{or} \quad \log(\text{m-TCE}) = \log A + a \operatorname{Log} Y + b \operatorname{Log} P \ldots\ldots (3)$$

where:

A, a, b - constant values to be determined by regression analysis
Y - GNP/capita (real prices)
P - Price index (for the base year it is 100)
mTCE - m Ton Coal Equivalent Energy consumption

Although the mathematical predictions have definite constraints for developing countries (due to social and political instabilities of these countries) they are the only tools for the feedback of any energy related policy.

Table 2 : Energy Consumption per capita in various countries of the world. Base year 1975 (4)

Country	m-Ton Coal Equivalent/Capita
U.S.A.	8.0
Canada	7.0
East Germany	5.0
USSR	4.0
England	3.8
Poland	3.6
France	2.9
Japan	2.6
Spain	1.6
Singapore	1.6
Korea	0.76
Turkey	0.6
Philippines	0.23
Kenya	0.16
Pakistan	0.13

Energy-importing developing countries such as Turkey and Kenya, have to take the challenge of exploiting all of their energy resources and to develop wise conservation measures which do not interfere with their healthy economic growth. Solar energy is one such resource. Its global abundance, renewable and non-depletable and environmentally acceptable character indicate that it will become one of the most important contributors to commercial energy supplies. Diurnal, seasonal and climatic variations must be considered as the disadvantages of solar energy. Because of these variations, the widespread use of solar energy entails either the extensive use of secondary storage (including an energy transport and distribution network) or hybrid use in conjunction with other sources to permit a reliable, non-interruptable energy supply.

The most favourable sites for collecting solar energy are in the areas between 35° north and south of the equator (8), also called as "solar-belt". Kenya and her neighbour countries are in the middle of this "solar-belt" and the study of Onyango and Beba (9) shows that average daily solar insolation is in the range of 400-500 Langleys (1 langley = 1 cal/cm^2). It is estimated that there are over 2 billion people (excluding China) living in the solar-belt. About 950 million of this 2 billion are the poorest people of the world. They live in rural communities of 50 to 200 families and are far away from all the development activities. It is obvious that solar energy in all forms (wind, biomass and direct solar conversion as heat or electricity) would have a very positive impact in the life styles of these people.

The utilization of solar energy in the solar rich developing countries could be planned in the following manner :

1. Short-term utilization

   a) Solar water heaters
   b) Green house applications
   c) Heating and cooling of buildings
   d) Cooking
   e) Pumping and irrigation applications
   f) Distillation of water
   g) Photo voltaic cells

2. Long-term utilization

   a) Solar furnaces
   b) Solar power generators
   c) Photochemical and photobiological conversions
   d) Thermochemical processes, hydrogen and methane production from water

In a survey carried out in Turkey (10) it was found out that, out of 60 scientists working in the field of solar energy there were 394 different research projects which could be grouped as :

1) 35 per cent on collector design and performance
2) 29 per cent heating buildings
3) 10 per cent on agricultural applications
4) 8 per cent in statistical data collection, measurement and theoretical predictions of solar insolations
5) 6 per cent storage of solar energy
6) 3 per cent solar furnaces
7) 1 per cent in Hydrogen production and Stirling engine applications
8) 8 per cent special applications (90 per cent of this for rural purposes)

As it is seen from the above tabulation special applications are rather important in commercializing the utilization of solar energy in developing countries.

RURAL APPLICATION OF SOLAR ENERGY

One of the large scale solar energy application is initiated by UNEP in Sri Lanka where wind, bio-gas and solar power (both as heat and electricity) are utilized to produce enough electrical and heat energy for the people of the village called Pattiyapola. Similar activities are also expected to be carried out in Senegal and Mexico (11). Another important rural application of solar energy is carried out at the UNICEF's "Rural Technology Centre" in Nairobi, Kenya. The Centre provides both the local and the visiting people to grasp the rather simple solar water heating and drying technologies as well as the utilization of wind energy by use of local labour and material. In Turkey, Ege University is co-operating with the Turkish Highway Department to develop a proto-type "solar-trailer".

The Highway Workers' Organization is very sensitive for the comfort of the workers who work (and live) in rural areas for road construction and repairs. The Turkish Highway Department had to comply with the demands of the Workers' Organization. One of the demands was to provide workers with hot water. The Highway Department conveyed the demand to Ege University requesting a design of a movable solar water heater as they were rather short with conventional heating sources. A model was designed for this purpose at Ege University and was constructed and tested by the Turkish Highway Department in one of their operations. The flat plate solar collectors were designed to produce 500 litres (20 workers x 25 litres/worker) 45°C hot water per day. These collectors were amounted on a truck. The side and the end views of this truck with respective dimensions are shown in Fig. 1. The truck is equipped with three showers and both the hot and the cold water storage tanks are mounted on the top. In the design, necessary precautions are taken into consideration to safeguard the "solar-trailer" from external abuse. One worker is needed to open up the covers and set up the collectors at the proper angle (by using a marked lever) for the reception of optimum insolation. Some of the connections between the collectors and the storage tanks are made out of flexible material (rubber). The system works with the principle of natural circulation. The concept of the "solar-trailer" was very well received by the workers. The construction season is between March to November of each year. In 1978 the truck was tested (during the construction period) and the results were very satisfactory. Once the reliability of the system is proven (by the end of 1979) it will be advised to be put into operation in other rural works such as in mining and oil exploration and production campsites. There are some private companies in Turkey showing great interest in the concept and are trying to adopt it to trailers as shown in Fig. 2 and Fig. 3.

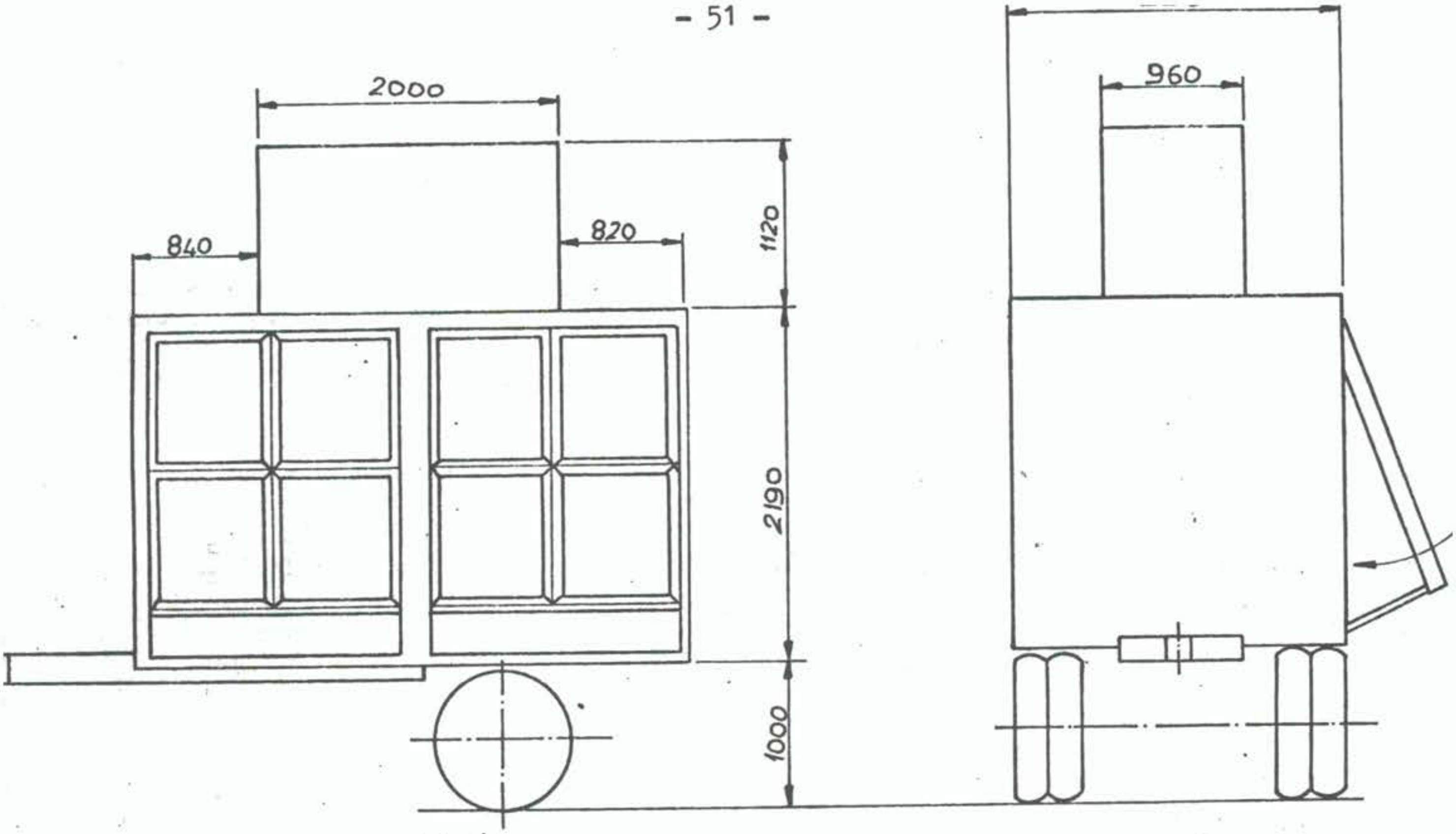

Fig. 1

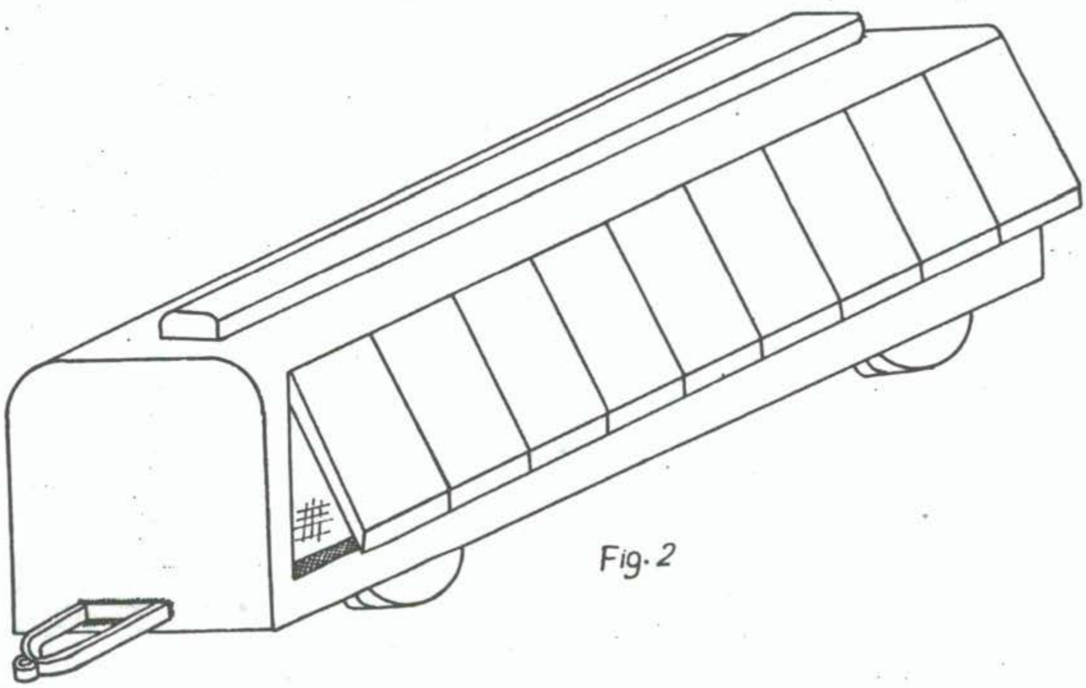

Fig. 2

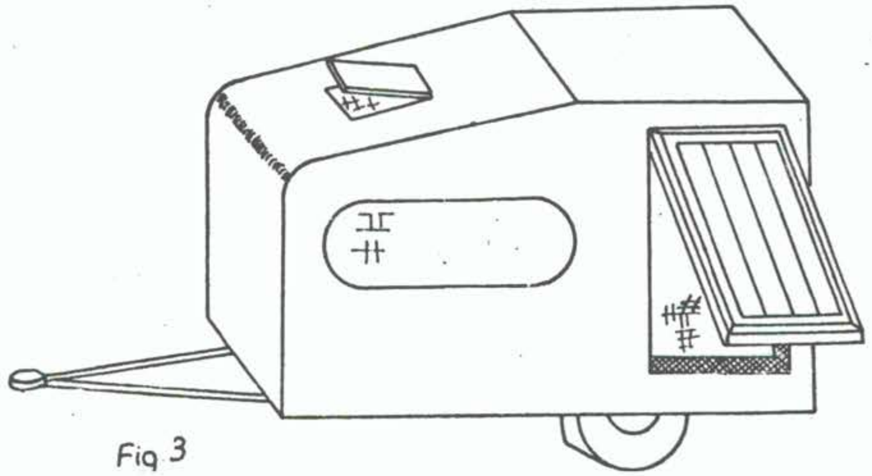

Fig 3

CONCLUSIONS AND SUGGESTIONS

1. Energy shortage did not have a balanced effect to developed and developing countries. Developed countries started to imply legislative measures to reduce the dependence on fossil fuels. They, in addition, developed policies for exploiting the new energy sources and therefore their economies were not disturbed. Energy importing developing countries, however, needed to have higher rates of energy consumption in order to increase the production of their exportable goods but they could not achieve this goal, because of the deficits on their balance of payments. Because of this unbalanced effect, the economic (and social) gap between developed and developing countries is widening.

2. In developing countries, much has been said and written in numerous meetings, on renewable energy sources since 1973. But not enough progress has been made in the application phases of these resources.

3. A realistic solar energy utilisation model based on the facts of the country is needed for solar energy to play its vital role in the solution of the energy predicaments of these countries.

4. Solar-rich developing countries should imply the proven solar technologies in the fastest possible rate.

5. Special applications of solar energy for rural areas such as the cases of Sri-Lanka, Kenya and Turkey stresses the fact that through technically and commercially attractive applications of solar energy (in all forms) a part of the energy demand of many of the less developed countries where solar energy is in abundance could be met.

REFERENCES

United Nations Statistical Yearbook, U.N. Publications (1976)

Hubbert, M.K., "The Energy Resources of the Earth", Scientific American, 224, pp.60-70 (1971)

Öziş, U., "Maximal Development of Power Resources", Tenth World Energy Conference Proceedings, Istanbul, Turkey (1977).

"Energy in Denmark - Past and Present", ISBN 87-87585-04-9, (1977)

McCrakis, M.S., "Energy: Demand, Conservation and Institutional Problems" MIT Press, U.K. (1973)

Abelson, P.H., "Energy: Use, Conservation and Supply", American Association for the Advancement of Science, Washington, D.C. (1974)

Beba, A., "Energy and Technology Centres for Rural Areas and Renewable Energy Sources", Energy Seminar at Cukurova University, Adana, Turkey (1979)

Duffie, J.R. and Beckman, W.A., "Solar Energy Thermal Processes", John Wiley and Sons, New York (1974)

Onyango, F.N. and Beba, A., "An Investigation of Solar Energy Distribution in East Africa - the Case of Kenya", Energy and Environment in East Africa, Nairobi, 7-10 May, 1979.

Solar Energy Meeting, Turkish Scientific and Research Council, Ankara (1979)

UNEP - GC Publications (1973)

SMALL HYDRO-ELECTRIC SCHEMES AND RURAL DEVELOPMENT

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SUMMARY

Small hydro-power schemes are unique in providing opportunities for accelerated development of rural areas far from the main electric grid in a country. At suitable locations, they can provide power that can be used to modernize agriculture, to develop agro-industries, cottage industries and to improve the quality of life in rural areas. An average size village would need a 40 KW to 500 KW power station depending on the number of inhabitants and patterns of use of electricity. In some countries, electricity produced during the day from small hydro-power installations is mainly diverted for use in agriculture and agro-industries, while that produced at night is mainly used for lighting.

INTRODUCTION

Energy has long been viewed as an essential ingredient to meet our basic needs and to stimulate and support economic growth and our standard of living, so much so that often a nation identifies its well-being with its gargantuan and growing need for energy.

The relationship of economic prosperity to energy consumption is an essential element to energy policy, for it couples the latter to economic policy and the general national welfare. Although there are anomalies in the amounts of energy required in different countries to achieve a given level of gross national product (GNP), there is nevertheless a rather consistent relationship between GNP and energy consumption. This close relationship has been valid historically, and analysis indicates that the correlation coefficients are uniformly and consistently high. Thus, as a country's GNP in real terms rises over time, its energy consumption goes up as well. However, the degree of dependence, economy vs energy, can be influenced by a variety of factors. For example, the structure of the economy will affect the correlation between GNP and energy consumption; the rate of increase of GNP and energy use is somewhat similar for energy-intensive exports, but for non-energy intensive exports, GNP increases at a much faster rate than energy use. Gradual and steady improvements in the efficiencies of energy conversion and utilization have shown up as historical trends indicating decreasing ratios between per capita energy consumption and per capita real GNP. The life-style preferred by a given society will also enter into this equation. The level of comfort in terms of temperatures maintained during summer and winter plus the levels of illumination in residential, commercial, and industrial structures is but one example. The preference for suburban living, mobility, and decreased reliance on mass transport furnishes another, and both examples, in their own way, can lead to increases in per capita energy consumption without a compensating increase in economic productivity. There are far too many other potential factors that could be listed here - the growing energy intensiveness of agriculture and the food industry, the displacement of natural products by synthetics, etc. are but some examples.

For the greater part of the last century the rising global demand for energy has been met to an increasing extent by the use of fossil fuels. This trend was encouraged by the comparatively low price of oil, which in many instances has not been used in the most efficient manner. With the ever-rising demand for fossil fuels there has been an accompanying realization that these energy resources are finite in extent and should, therefore, be regarded as wasting assets.

The general realization of the finite nature of fossil fuel resources has caused a re-examination of the possibility of using those energy resources which are of a non-depleting nature and, therefore, considered renewable. These energy sources are increasingly important both in developed and in developing countries. In the former countries, strategies for the exploitation of such sources constitute a part of recent conservation policies which aim at reducing the dependence on fossil fuels to satisfy the growing needs for energy. In the developing countries, particularly those short of fossil fuel resources, the renewable sources of energy constitute a promise for meeting a part of the future energy needs, at a reasonable price, to accelerate the process of development, particularly in rural areas.

HYDRO-POWER

Man's earliest extensive use of energy, other than muscle power of man and animals and direct solar energy, was that derived from flowing water. The use of waterwheels of various types extend back to the early civilizations. The size and efficiency of waterwheels increased over the centuries, and in the nineteenth century, water-powered mills of various types ushered in the beginning of the industrial age. The peak of this early water power development phase was reached about the middle of the nineteenth century because favourable mill sites, within the reach of the mechanical transmission of power, were limited. Furthermore, at the time, the more flexible steam engines were improving in economy and dependability. With the advent of electricity in the 1880's, and with alternating current technology making transmission of electric energy more economical, the development of hydroelectric energy was well underway by the beginning of the twentieth century. Developments were rapid and by the 1930's, projects such as the 1.3 million kW powerhouse at Hoover Dam in the U.S.A. were completed. Large hydroelectric installations such as this increased the utilization of energy in the industrialized countries and programmes to utilize the large hydroelectric potentials were pushed ahead.

The growth of electricity production from hydro-power has considerably increased since the 1950's; in 1976, the hydroelectricity production reached 1456×10^9 kWh constituting about 21% of the total world electricity production in that year (see Table 1).

Table 1. World Electricity Production (in 10^9 kWh)*

Year	Thermal	Hydro	Nuclear	Total
1972	4226	1294	144	5664
1973	4583	1313	191	6087
1974	4580	1439	246	6265
1975	4660	1459	343	6462
1976	5063	1456	398	6917

* After: World Energy Supplies 1972-1976, United Nations (1979).

The total potential from hydro resources of the world has been estimated at 2.2 x 10^6 MW of installed and installable generating capacity at 50% capacity factor (Armstrong, 1978). The potential annual energy production from these sources amounts to 9779 x 10^9 kWh, which is 6.7 times the hydroelectric production in 1976. Table 2 gives the geographical distribution of that potential.

Table 2. World hydro-power resources*

	Installed and Installable generating capacity (MW at 50% capacity factor)	Annual Production capacity (10^9 kWh)	% of Total
Asia	610,000	2694	28
S. America	431,900	1907	20
Africa	358,300	1582	16
N. America	356,400	1574	16
U.S.S.R.	250,000	1103	11
Europe	163,000	720	7
Oceania	45,000	199	2
Total	2,214,600	9779	100

* Calculated After Armstrong (1978).

To produce 9779 x 10^9 kwh would require the burning of about 15 billion barrels of oil or 40 million barrels of oil per day in oil-fired thermal power station.

The ope rating hydroelectric capacity at present is about 372,000 MW with an annual production of about 1600 x 10^9 kwh, which is approximately 16% of the total reported installed and installable potential (Armstrong, 1978). Although more than 65% of the hydro potential in Europe and about 50% of the potential in North America has been exploited, less than 8% of the hydro resources in developing countries has been harnessed for energy production (about 9% in Asia, 8% in South America, 6% in Africa has been exploited).

Hydro-power is an important source of energy not only because it is renewable but also because it is non-polluting energy source (no emissions or thermal discharges) and constitutes an integral part of optimum overall water resource utilization. It is an important part of large electric power systems because of its reliability and flexibility; it is a catalyst in socio-economic development, particularly in rural areas of developing countries (El-Hinnawi, 1977) and its economic justification is improving because of its "inflation proof" characteristics and its long life and low maintenance costs (Armstrong, 1978). It should be noted, however, that in order to maximize the benefits of hydro-power, it should be developed as a part of an overall water development plan. The development of large-scale waterpower per se in some developing countries, for example, has created a number of socio-economic problems. One consideration being that the output of large amounts of electricity requires, for example, expensive transmission lines and a societal and economic structure ready to take advantage of this form of energy (Kristoferson, 1977). Low density of population, long distances between energy consumption centres, and low income levels are some factors that often hamper the growth of electricity consumption among the population at large. Because of the large investments necessary for many dams, in many cases only very large-scale industrial operations are regarded as economically profitable. This may result in large, energy-intensive industries being constructed to match the output of large power stations. The influence of this type of industrial development on a general societal development in developing countries is sometimes questioned. Adequate planning and cost/benefit analysis is, therefore, an important prerequisite in the development of hydro-power installations.

Hydroelectric generating plants vary considerably in size, from as small as 3 kW (El-Hinnawi, 1977) to as large as 12×10^6 KW (ICOLD, 1977). Small hydro-power stations (also called mini-hydro, village-size hydro-power installations ... etc.) are generally those with installed generating capacity less than 1000 kW*. Such stations are normally built as part of water management and rural development strategies. In the People's Republic of China, for example, more than 60,000 small hydro-power stations, with a total generating capacity of about 3000 MW were built in the last 15 years (El-Hinnawi,1977) in rural areas. This has largely accelerated the development of such areas by providing power for better irrigation schemes, small agro- and rural industries and domestic use. There is no technical reason why such small hydro-power schemes should not be built in rural areas of other developing countries using any suitably available water course (canals, rivers, reservoirs, falls ....etc.).

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* Smil (1976) defines small hydro stations as those with capacities less than 500 kW, whereas in the People's Republic of China, small hydro-power schemes are those having installed generating capacities less than 12,000 kW (El-Hinnawi, 1977).

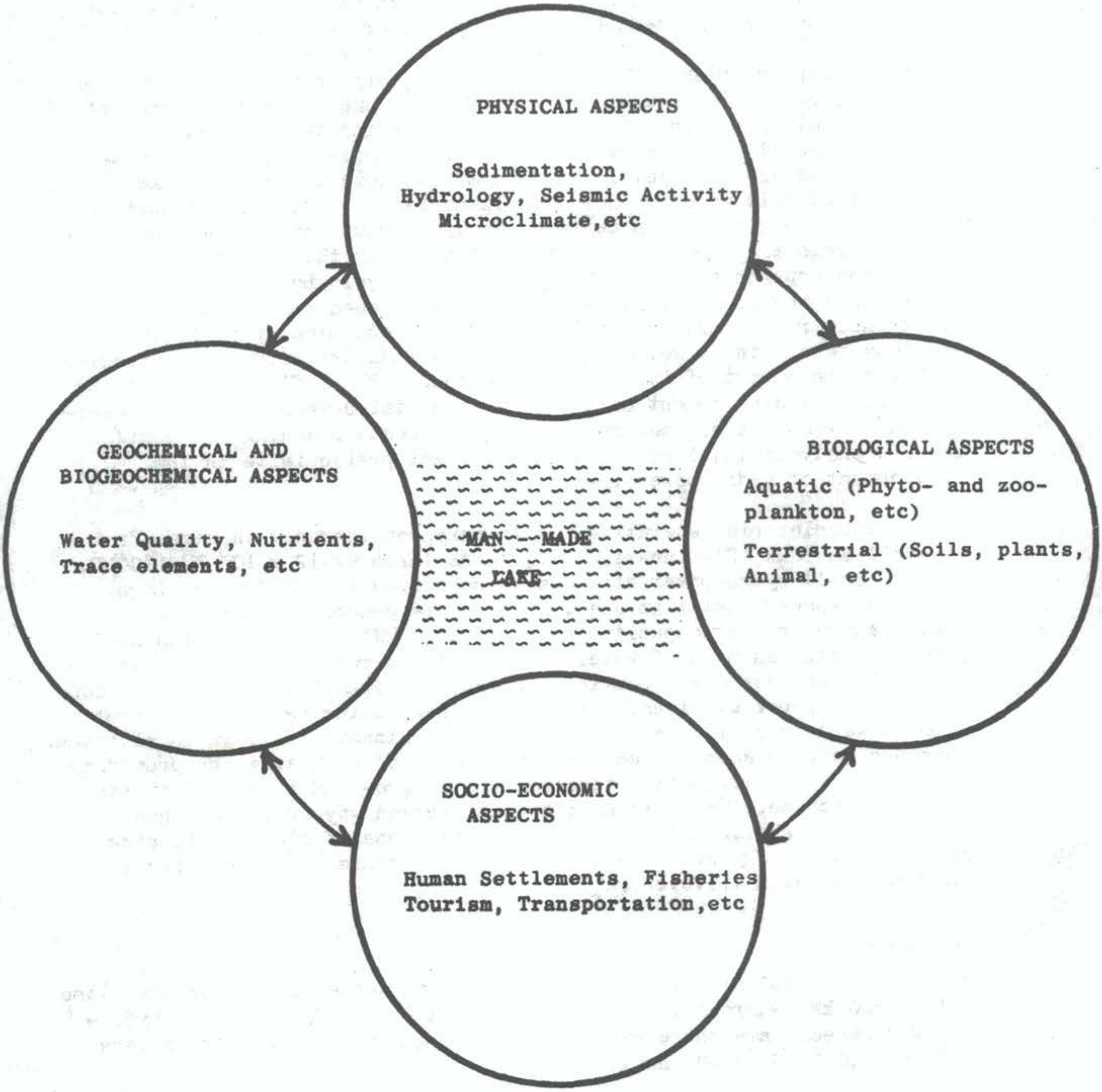

Fig. 1 Environmental Aspects of Man-Made Lakes (After El-Hinnawi, 1978)

Environmental Aspects of Hydroelectricity Generation

Hydroelectricity generation has a number of environmental impacts. No dam can be built and no lake can be created without environmental costs and benefits of some kind. A dam becomes a dominant factor in the hydrological regime, and sets in motion a series of impacts on physical, biological and socio-cultural systems. The many consequences on the environment of the dam and the lake behind it appear to be factors in common regardless of the dam's geographical location. However, the environmental effects of reservoirs located in tropical areas occur more quickly than those located in temperate zones. The environmental side-effects of dam construction are generally divided into two categories : (a) the local effects and the reactions with the area of the man-made lake; (b) the downstream effects resulting from a change in the hydraulic regime. Both categories have their physical, biological and socio-economic elements.

The environmental impacts of man-made lakes and the reactions within the area of the lake are summarized in Fig. 1. It should be noted that these effects are interrelated and that they affect each other. The construction of a dam and the filling of its reservoir cause substantial local change by introducing an immense structure into a natural setting. The flooding of the region could have immediate significant impact on the means of communication, historic sites, communities which are inundated, and the local flora and fauna. The dam itself presents an obstacle not only to the free running of water, but also to fish migration and navigation. Continued fish migration may be achieved by the construction of fish ladders, or by collecting fish and transporting them by road. In the case of some very high dams, artifical conditions favourable to spawning have been constructed below the dam, and eggs cultured under ideal conditions in hatcheries. While this is a costly process, it can ensure the survival of larger numbers of eggs and fingerlings than possible under natural conditions. Care must also be taken to assure migration during dam construction.

Physical Aspects

Although it is designed to store water, a man-made lake immediately begins to store sediment carried by the stream. The amount of sediment deposited in a given reservoir depends on the amount of sediment delivered to it and the reservoir's ability to retain the sediment. Therefore, reservoirs differ greatly in the amount of sediment deposited in them because of the tremendous variability, both in time and space, in the amount and characteristics of the sediment carried by streams and the circumstances causing its deposition. Dendy et al. (1973) found that in the U.S.A., the average storage loss was 3.5% annually for small reservoirs (with a capacity less than about 10000 m^3) and that the storage loss decreases with increase in the storage capacity (the loss was about 0.16% for reservoirs with a capacity greater than 10^9 m^3). Cyberski (1973) pointed out that the storage depletion was 0.51% per year for 19 reservoirs in Central Europe (ranging in capacity from 1.5×10^5 to 23×10^6 m^3). In Lake Nasser, Egypt, it has been estimated that the reservoir was losing about 60 million m^3 of storage per year due to siltation in the first few years of its filling. At this rate, the dead storage capacity of 30 km^3 will be filled in about 500 years (Biswas, 1978).

The effects of sediment deposition in reservoirs are evidenced in many ways but perhaps most significantly in terms of the reservoir's ability to perform its intended functions. Water resource functions most commonly served by reservoirs include water supply, irrigation, flood control, hydroelectric power, navigation, recreation ... etc. To the extent that sediment distracts from the services provided or expected from a reservoir, it is a liability expressible as the lesser of either (a) the cost of services foregone because of the sediment or (b) the cost required to remove the sediment from the reservoir or to keep it out in the first place (Glymph, 1973). Depletion of storage capacity is but one of the upstream effects of reservoir sedimentation. The stream channel is likely to aggrade for some distance above the reservoir because of backwater effects on sediment transport. The formation and growth of deltas tend to accelerate and extend the process still further upstream. Thus channel gradients become flatter, channel cross sections are reduced, flooding occurs more frequently, and drainage of floodplain lands is impeded because of reservoir sedimentation. On the other hand, as a result of the siltation in the reservoir, clear water flowing downstream cause channel degradation and stream bank erosion. The sediment-free water passing through the reservoir can entrain another sediment load and proceeds to do so where the material is available. The phenomenon applies downstream from both large and small reservoirs. It is most likely to occur when a dam is built on an alluvial channel that previously had a generally stable relationship between such factors as stream discharge, sediment load, channel gradient, and widths and depths of stream channel. Another effect of the siltation in the reservoir is possible erosion of the river delta. Prior to the construction of the Aswan High Dam, for example, the Nile Delta used to be built up during the flood season, with the silt carried by the River to the Mediterranean. This situation in the Delta compensated for the erosion that resulted from the winter waves of the preceding year. Without enough siltation, erosion of the Delta has become a major problem (Biswas, 1978).

Changes in quality and quantity of sediments downstream are believed to affect agriculture and fish production many ways. Whereas, theoretically the principles involved in the foregoing surmises are sound, whether the apprehended effects do, in fact, occur in a given river is debatable and is dependent on various features of the river itself, such as the silt content of the waters, the nutrient status of the silt, the extent of flooding, and so on. It is well-known that due to deprivation of the annual nutrient silt deposits due to the Aswan High Dam, substantial amounts of fertilizers have to be used to recharge the soil downstream with nutrients (El-Hinnawi, 1978). The lack of Nile sediment has also led to the migration of sardines and crustaceans from their habitat in the Mediterranean north of the Delta. However, there are no precise studies establishing a cause and effect relationship between the Aswan Dam and the disappearance of the sardines, notwithstanding the fact that the postulates in support of this surmise appear to be theoretically sound. Sardines have disappeared elsewhere in the world in situations completely unrelated to dam construction. They have equally mysteriously reappeared after a lapse of some years (for example, in the Indian Ocean).

Man-made lakes generally alter not only the streamflow regime but also the water balance (and the hydrological cycle). These effects may be of particular significance in arid and semi-arid regions. Comparative studies have shown that the construction of several small and medium size storage reservoirs has reduced the annual flow by 10% in average years and by 25% during dry years in a 2000 km^2 semi-arid river basin in northeast Brazil (Dubreuil and Girard, 1973). In some areas, where the permeability of the substrate is high, vast amounts of water are lost by seepage from the reservoir. Lateral seepage from Lake Nasser, for example, has been estimated to reach 1000 million m^3/year (Abu Wafa and Labib, 1973). On the positive side, this seepage has led to changes in volume and direction of ground water flow, facilitating reclamation of low-lying arid lands at considerable distances from the lake (El-Hinnawi, 1978). On the negative side, however, the increase in the water table downstream has led to the production of bog effects and in some cases salinization that adversely affects the agricultural use of the soils (Biswas, 1978).

The filling of a lake imposes new stresses on the earth's crust that, in turn, generate seismic movements and that, in some cases, generate earthquakes that are severe enough (6 on the Richter scale) to cause human losses. These seismic activities may vary in magnitude and time in accordance with a number of factors. Water height of more than 100 m in a reservoir constitutes a factor that may be of major seismic importance in combination with geologic formation and structure (Rothé, 1973). Moreover, the saturation of sedimentary formations by seepage from the reservoir may cause additional seismic movements. Seismic activities have been recorded for a number of dams and associated reservoirs (Rothé 1973) and in some cases have led to catastrophes. For example, the earth movements that caused the collapse of the Vaiont Dam in Italy in 1963 (which caused the death of more than 2000 persons) were preceded by several years of considerable seismic activity characterized by a clear relation between the frequency of shocks and the progress of filling the reservoir. The Koyna dam disaster of 1967 in India, which resulted in some 177 deaths was attributed to an earthquake whose epicentre coincided with the dam itself, the reason for the earthquakes is believed to be tectonic activity rather than due to the reservoir (Rothé, 1973).

Relatively little is known about the precise influence of man-made lakes on weather and climate. At the microclimatic level, most of the evidence comes from comparison with natural lakes and their influence on precipitation, direction and frequency of wind, thunderstorms, hail, snow, and other phenomena. The impact of a man-made lake on temperature and precipitation is related to both local conditions and mesoscale meteorological elements and should be assessed for each site separately (Nemec, 1973).

Geochemical and Biogeochemical Aspects

The physical, chemical and biological properties of the water leaving a lake may differ significantly from the waters entering the lake. A large number of factors affect this quality transformation process, and the water conditions of the lake are of basic importance in understanding, predicting, or influencing these changes. Seasonal temperature fluctuations governed by the energy regime are the most common causes of a density stratification, but other agents such as dissolved or suspended solids can also be influential. Beyond differences in densities (temperature) at different depths, the rate of flow through a given cross section is the principal factor determining the possibility of the formation of a stagnant layer or distinct water masses in the reservoir. In many cases, hydrogen sulphide is found in these stagnant layers imparting obnoxious odour and creating a fishless void. Water stratification in the reservoir created by the Roseires Dam on the Blue Nile caused heavy fish mortality in 1967, when deoxygenation affected the water temporarily (El-Hinnawi, 1978). In many reservoirs the human discharge of waste has a significant effect on water quality, often as a result of measures not taken into account when the reservoir was planned. Flows of domestic and industrial effluents, of farm waste, and of excess fertilizers and pesticides may drastically modify the quality of stored water and of that discharged downstream.

Biological Aspects

The construction of a dam and the creation of the associated reservoir has a number of impacts on terrestrial and aquatic biota which are of four main kinds: (a) those of short life-span and frequent population turnover (e.g., nutrient-cycling bacteria and many algae), (b) those of intermediate life-span and turnover (e.g. cereal crop plants, some small fish), (c) those of long life-span and slow population turnover (e.g. perennial plants and large quatic or terrestrial animals or domestic livestock), and (d) people. The impacts of dam construction on these ecosystems should be assessed in detail and the actual and potential benefits of not undertaking versus undertaking the scheme should be determined. In this regard the elimination of terrestrial production in the inundated land should be carefully assessed. This production may be natural, i.e. culminating in wild plants and animals; however, it may be managed production, i.e., yielding agricultural crops, livestock, or forest crops. Also the elimination of actual and potential riverine production can be compared to anticipated gains from production in the new lake.

When the reservoir begins to fill for the first time, the terrestrial and riverine environments progressively disappear, and the lacustrine environment originates and expands. The interrelationships between the biological system and other components of the ecosystem are in rapid transition. As the reservoir changes, the plant and animal communities also change. In the lake basin, there is a sequential shift from dominance by flowing water species and communities to dominance by those of more quiet water. During the rapid development of the lacustrine system, an increase in bioproductivity is encountered manifested by production of planktonic algae and increase in fish production. During the stabilization process, lake evolution is irregular in speed and direction; after stabilization, future change is slowed and is usually overall in a predictable direction. In the stabilizing period the first benefits in fisheries and agriculture become available. For example, fish catch, as a partial indicator of production, in the section of the Volta River later covered by Volta Lake changed within 5 years from 4000 to some 60000 tonnes per year in the new lake (Ackermann et al., 1973). Raheja (1973) and Latif and Rashid (1973) reported an increase in fish production from Lake Nasser, Egypt from 764 tonne in 1966 to 4560 tonne in 1969; FAO (1974) reported 8343 tonne in 1972. At this time, explosive development of nuisance weeds has also occurred. In the tropics, nuisance weeds include the water hyacinth, water fern, and water chestnut. One of the more evident characteristics of a lake in the process of stabilization can be a rise or decline in the area covered by emergent equatic weeds and the occurrence of dense phytoplankton blooms.

The stabilized stage in the life history of a man-made lake is reached when fluctuations in its biological parameters of production exceed only slightly, if at all, those in a natural lake of similar physical characteristics and like latitude and elevation. As an example, stabilization would be characterized by a seasonally cyclic balance in the oxygen budget of the lake. Stabilization is also shown by the emergent aquatic plants when their rapid initial spread has ceased, attained an extent from which there is little annual change, or even retreated from an initail maximum extent as it has at Lake Kariba (Ackermann et al., 1973). The development of the terrestrial ecosystem around the lake depends on the overall development plans of the region. Agriculture and livestock management activities are important elements of such development. In Egypt, for example, FAO (1974) reported that about 100,000 hectares around Lake Nasser are suitable for agriculture.

Once the impoundment has been completed, the succession of plant growth colonizing the shorelines, and at times even the body of the lake, will influence the incidence and development of vector-borne diseases. Excessive weed or algal growth downstream as a result of the biogeochemical changes in the water quality of the river or due to changes in the irrigation system (e.g. from basin to perennial) will also influence the incidence of such diseases. Not only will such vegetation promote the breeding of schistosome-bearing snails and malaria mosquitoes, but it could also encourage the development of the filariasis vectors (Brown and Doem, 1973). Available evidence from the major man-made impoundments in Africa clearly indicates that transmission of schistosomiasis is taking place in the main body of every lake as well as in the existing irrigation works. It is important to emphasize, in this context, that the definitive host, man, is responsible for the dissemination of schistosomiasis by contaminating the equatic environment, where he in turn becomes infected. The snail is only a passive intermediate host. Thus the containment and abatement of schistosomiasis calls for management of the impounded water by means of shoreline sanitation, education of the human population to improve its habits in disposing wastes and excreta, and sanitary engineering to minimize the contacts between man and lake water. These measures are particularly important in view of the impossibility of applying molluscicides over an entire lake to control the snail populations chemically (Brown and Doem, 1973). Devastating epidemics of malaria have been recorded following construction of some dams. However, many recently created man-made lakes in Africa have not shown any patent malaria resurgence. Onchocerciasis in Africa is mostly transmitted by simulium damnosum, whose larvae breed in the rapid sections of streams and rivers. The effect of impoundments is beneficial insofar as they drown out the breeding places for several kilometers above the dam. Although breeding may subsequently take place on the spillways and below the dam, the larvae may be artificially flushed away by opening the sluice gates.

Socio-Economic Aspects

When a man-made lake is created, the members of the lake basin population are displaced, crowded or supplemented by new migrants. Within the lake basin the human population can be divided into four general categories, of which the first two pose the most problems. These categories are (a) those who must relocate because their homes and fields will be partially or totally inundated by the reservoir (the relocatees), (b) those among whom most of the relocatees must be resettled (the hosts), (c) those lake basin inhabitants who are neither relocatees nor hosts and (d) immigrants who move into the lake basin and seek new opportunities that accompany dam construction and reservoir creation. Most of the displacement exercises of the population has created several human problems. Thus, the Volta Dam in Ghana has inundated an area of about 3275 sq. miles, and the resulting lake has a shoreline of over 4000 miles. As a result of the development, some 78000 people and more than 170,000 domestic animals had to be evacuated from over 700 towns and villages of different sizes. Eventually, 52 new settlements were developed to house 69149 people from 12789 families (Jones and Rogers, 1976). It was a major problem since a large number of people coming from small villages (600 of the 700 original villages had less than 100 people, and only one had a population of over 4000), and having different ethnic backgrounds, traditions, religions, social values and cultures, had to be resettled into only 52 locations. The complex emotional relationships between the different tribes and their lands were not properly understood. The development of a socially cohesive and integrated community, having a viable institution infrastructure became hard to achieve. Similarly, the Kariba Dam on the River Zambesi (Zambesi and Rhodesia) displaced approximately 57000 Tonga tribesmen, who had to pay a major price for this progress. Technology transfer at that level was a major problem, since many of the planners were from outside Africa. The resettlement programme for the Tonga tribesmen left much to be desired; not only did they suffer great cultural shocks when being thrust into communities as different from their own, as theirs from Great Britain, but also it took two years to clear sufficient land to meet their subsistence needs. The government had to step in to avert famine and very serious hardships and, ironically, this good-intentioned step became one of the most destructive parts of the process. The food distribution centers also became transmission sites for the dreaded sleeping sickness disease. Similar results from water development projects have, unfortunately, not been unique. Approximately 100,000 people had to be relocated for the Aswan High Dam without sufficient planning, and the World Food Programme had to rush in famine relief for the Nubians. Other examples of lakes and populations displaced are the following : Lake Kainji in Nigeria - 42000; Keban Dam in Turkey - 30000; and Ubolratana Dam in Thailand - 30000 (UNEP, 1977). Resettlement of population due to water development projects in many developing countries has not been a satisfactory experience. Inadequate planning, insufficient budget, incomplete execution of plans and little appreciation of the problems of technology transfer have all contributed to the failure of plans. The fact that much of the population to be resettled were rural and illiterate, and thus had very little political power, did not help either. The direct beneficiaries of the projects were often the educated elites, who are in power, whereas the direct social costs were mostly attributable to the rural poor (Biswas, 1978).

On the other hand the building of dams and the creation of reservoirs have a number of socio-economic benefits: better water management and development of irrigation systems to increase agricultural land and production of power needed to accelerate industrialization and socio-economic development. The lake itself provides opportunities for a number of socio-economic activities ranging from agriculture on the sides of the lakes, to fisheries, tourism and the development of small industries.

Although the negative environmental impacts of man-made lakes are pronounced in the case of large dams and hydro-power installations, the impacts of small lakes are insignificant. This, however, does not preclude that in certain ecological zones the impacts of changes in the aquatic environment could have marked effects. It is, therefore, necessary to study the environmental consequences of small hydro-power installations at an early stage in the design and construction and to monitor changes in the aquatic environment at later stages to remedy any adverse effects that may occur.

REFERENCES

Abu Wafa, T. and A.H. Labib (1973): Seepage Losses from Lake Nasser In: Ackermann et al. : Man-Made Lakes. Amer. Geophysical Union Monograph 17.

Ackermann, W.C. et al. (1973): Man-Made Lakes: Their problems and Environmental Effects. Amer. Geophysical Union. Monograph 17.

Armstrong, E.L. (1978): Hydraulic Resources. In World Energy Resources 1985-2020 World Energy Conference IPC Science and Technology Press.

Biswas, A. (1978): Water Development and Environment. IIASA Paper pp - 78-5.

Brown, A.W.A. and J.O. Deom (1973): Health Aspects of Man-Made Lakes. In: Ackermann et al: Man-Made Lakes. Amer. Geophysical Union Monograph 17.

Cyberski, J. (1973): Accumulation of debris in water storage reservoirs of Central Europe. In: Ackermann et al. : Man-Made Lakes. Amer. Geophysical Union. Monograph 17.

Dendy, F.E. et al. (1973): Reservoir Sedimentation Surveys in the United States. In: Ackermann et al.: Man-Made Lakes. Amer. Geophysical Union. Monograph 17.

Dubreuil, P. and G. Girard (1973): Influence of a very large number of small reservoirs on the annual flow regime of a tropical stream. In: Ackermann et al. : Man-Made Lakes. Amer. Geophysical Union. Monograph 17.

El-Hinnawi, E.E. (1977): Energy, Environment and Development 10th World Energy Conference. Istanbul 1977 paper 4.8-1.

El-Hinnawi, E.E. (1977): China Study Tour on Energy and Environment. Technical Report. United Nations Environment Programme, Nairobi.

El-Hinnawi, E.E. (1978): The State of the Nile Environment. Workshop on Nile Environment. Egyptian Environmental Soc. Cairo.

FAO (1974): Lake Nasser Area, Agricultural Potential. FI: DP/EGY/66/558. Tech. Report 4. FAO, Rome.

FAO (1974): Fish Yield Projections on the Nasser Reservoir. FI/DP/EGY/66/558. Techn. Report. 5. FAO, Rome.

Glymph, L.M. (1973): Sedimentation of Reservoirs. In: Ackermann et al: Man-Made Lakes. Amer. Geophysical Union. Monograph 17.

ICOLD (1977): Contributions of Dams to the solution of energy problems. International Commission Large Dams. 10th World Energy Conference. Istanbul. 1977.

Jones, J.O. and P. Rogers (1976): Human Ecology and Development of Settlements. Plenum Press, New York.

Kristoferson, L. (1977): Water power - A short Overview. Ambio VI, p.44.

Latif, A. and M. Rashid (1973): Catch of Fish from Lake Nasser. In: Ackermann et al., : Man-Made Lakes. Amer. Geophysical Union. Monograph 17.

Nemec, J. (1973): Interaction between Reservoirs and the Atmosphere. In: Ackermann et al. : Man-Made Lakes. Amer. Geophysical Union Monograph 17.

Raheja, P.C. (1973): Lake Nasser. In: Ackermann et al: Man-Made Lakes. Amer. Geophysical Union. Monograph 17.

Rothé. P. (1973): Geophysics Report. In: Ackermann et al. : Man-Made Lakes. Amer. Geophysical Union. Monograph 17.

Smil, V. (1976): Exploiting China's Hydro potential. Water Power and Dam Construction. March 1976 p.19.

United Nations (1979): World Energy Supplies 1973-1978. Statistical Paper J 22. UN New York.

UNEP (1977): Environmental Issues in River Basin Development UN Water Conference, E/CON.70/A.26. United Nations, New York.

ROLE OF ELECTRICITY IN THE DEVELOPMENT OF ENERGY POLICY FOR KENYA

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INTRODUCTION

Electricity is a secondary form of energy converted from primary sources like water-power, oil, geothermal, gas, wood, coal, nuclear, wind-power, sun and host of similar sources of energy.

Kenya has no known resources of oil, coal, gas or nuclear energy. Known water resources will be fully exploited within the next 15 to 20 years. Geothermal is still in its early stages of development and its potential is estimated to be between 170 and 500 MW. Kenya's various resources are depleting rapidly, and with the demand for energy growing steadily due to increase in population, higher industrialisation and modernisation of rural sector of the economy; the country faces an energy crunch for which there is no easy solution.

The indigenous resources available in the country for the production of electricity will continue to be exploited to the full but to sustain the economic growth of the country, Kenya must continue to depend on the importation of oil. It would not, therefore, be out of place to discuss briefly the energy situation in the international context.

The price of oil was increased five-fold in 1973 by OPEC countries. These oil prices may have seemed to have happened overnight in response to a specific and unpredictable political climate. But this was not the only reason. Other, more fundamental, factors were at work. By early 1970, the technological progress had flattened out; most of world's large petroleum resources in conventional exploration areas had been discovered. For the first time in history, the market was not able to provide a cheaper replacement fuel as oil and gas reserves declined, as it did when coal replaced wood and later when oil and gas replaced coal. Prospective new energy sources such as oil from shale, oil or gas from coal nuclear and solar energy are more expensive than oil. In other words, in the long run, the marginal cost of energy exceeded average costs of energy.

It follows that Kenya, where natural resources for production of energy are more scarce than the rest of the world, must continue to depend on imported fuel and that cost of energy in whatever form, must continue to rise. This is a basic fact which must be borne in mind by planners and policy makers.

TABLE 1: CONSUMPTION OF ENERGY EXPRESSED IN TERMS OF PRIMARY SOURCES

Form of Energy	Oil Equivalent ('000 Tonnes)		Percentage Annual Rate of Increase	Per cent of Total Energy Consumed		Forecast 1983	
	1973	1977	1973-77	1973	1977	Oil Equivalent ('000 Tonnes)	Per cent Share
Coal and Coke ..	50.0	43.8	-2.9	3.2	2.3	36.3	1.5
Oil	1,359.9	1,605.90	4.2	86.0	85.0	2,085.3	84.7
Electricity ..	170.4	232.6	8.1	10.8	12.4	339.0	13.8
TOTAL ENERGY	1,580.3	1,806.5	4.5	100.0	100.0	2,460.6	100.0
Import as percentage of total energy consumed ..	83.0	74.4					
Per Capita Consumption in terms of kg. Oil Equivalent ..	127	131					

ELECTRICITY IN RELATION TO OTHER FORMS OF ENERGY

Electricity as a Part of Total Energy Consumption:

While no reliable data is available on wood and charcoal consumption in the rural sector, Table 1 extracted from the National Development Plan 1978-83 gives some indication of the consumption of electricity in relation to other forms of energy in the modern sector.

As can be seen from Table 1, oil plays a very predominant role in the modern sector of energy in Kenya. Electricity, however, is expected to play a more significant role during the next 10 to 15 years as more and more hydro and geothermal potential is developed.

Available Sources of Primary Energy for Generation of Electricity:

Graph 1 gives the pattern of growth of electricity up to the year 2000 and the primary sources of energy which will be deployed in producing this electricity. In 1979, about 80% of electricity produced will be from hydro generation. By 1993, its share will increase to 90% and then decline to about 40% by the year 2000 as most of the hydro electric resources would have been exploited. From 1993 onwards, oil will again start playing a more predominant role and imported nuclear energy could well be considered as alternative to and additional to oil.

Utilisation of Electricity:

Graph 2 gives the pattern of electricity growth up to the year 2000 and the way the electricity will be utilised for different categories of customers. It is expected that by the year 2000, 65% of the electricity used will be for industry and the rest 35% for domestic and commercial use.

COST OF ELECTRICITY

Without going to too much detail in computing the present day cost of electricity, Table 2 below gives the breakdown of costs in interconnected, isolated and rural areas:

Table 2: Average Cost of Electricity

Global Costs in Kenya:

a) Interconnected System:

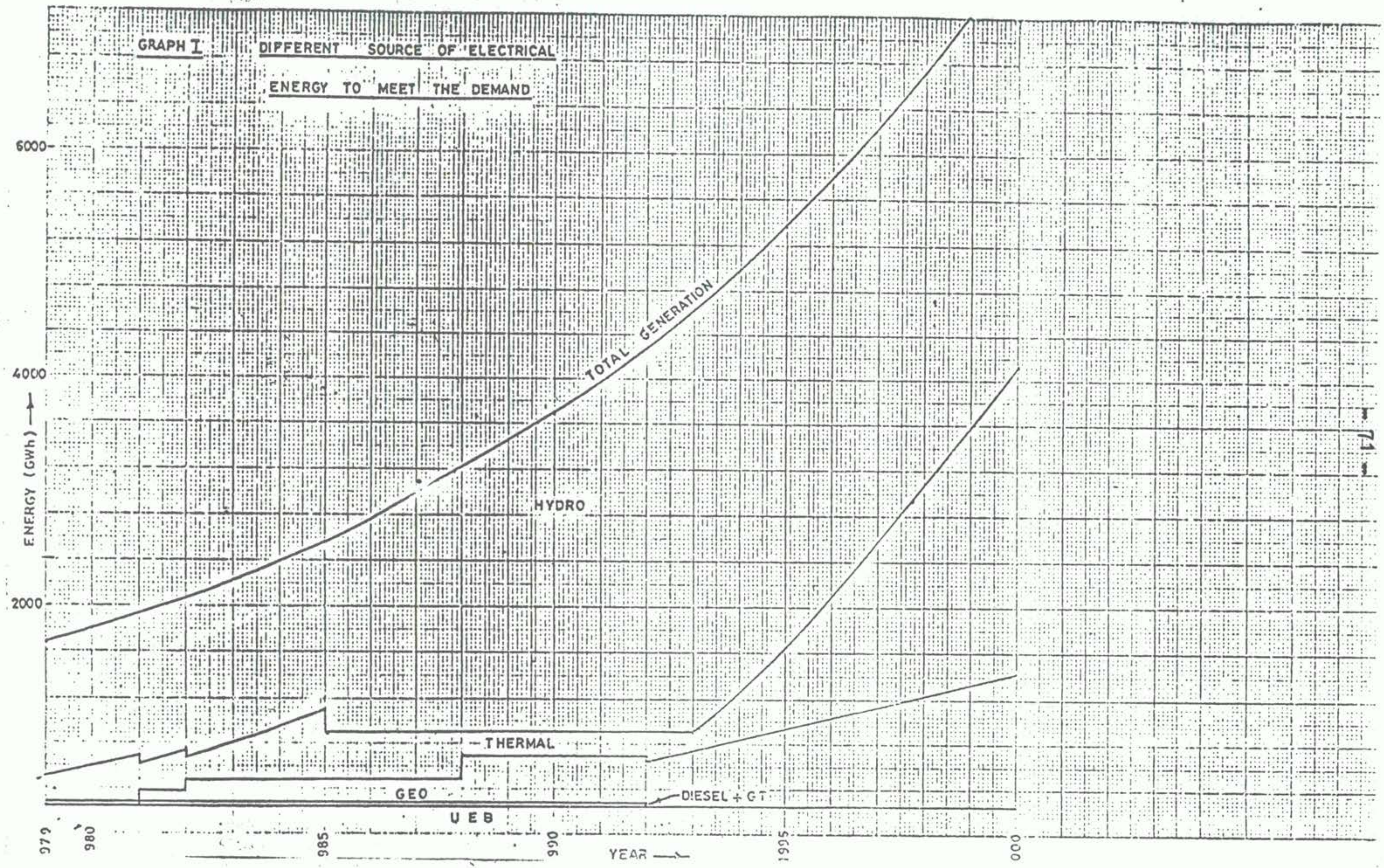
Generation	Cents 20 per unit
Transmission	" 5 " "
Distribution	" 5 " "
Total	Cents 30 per unit

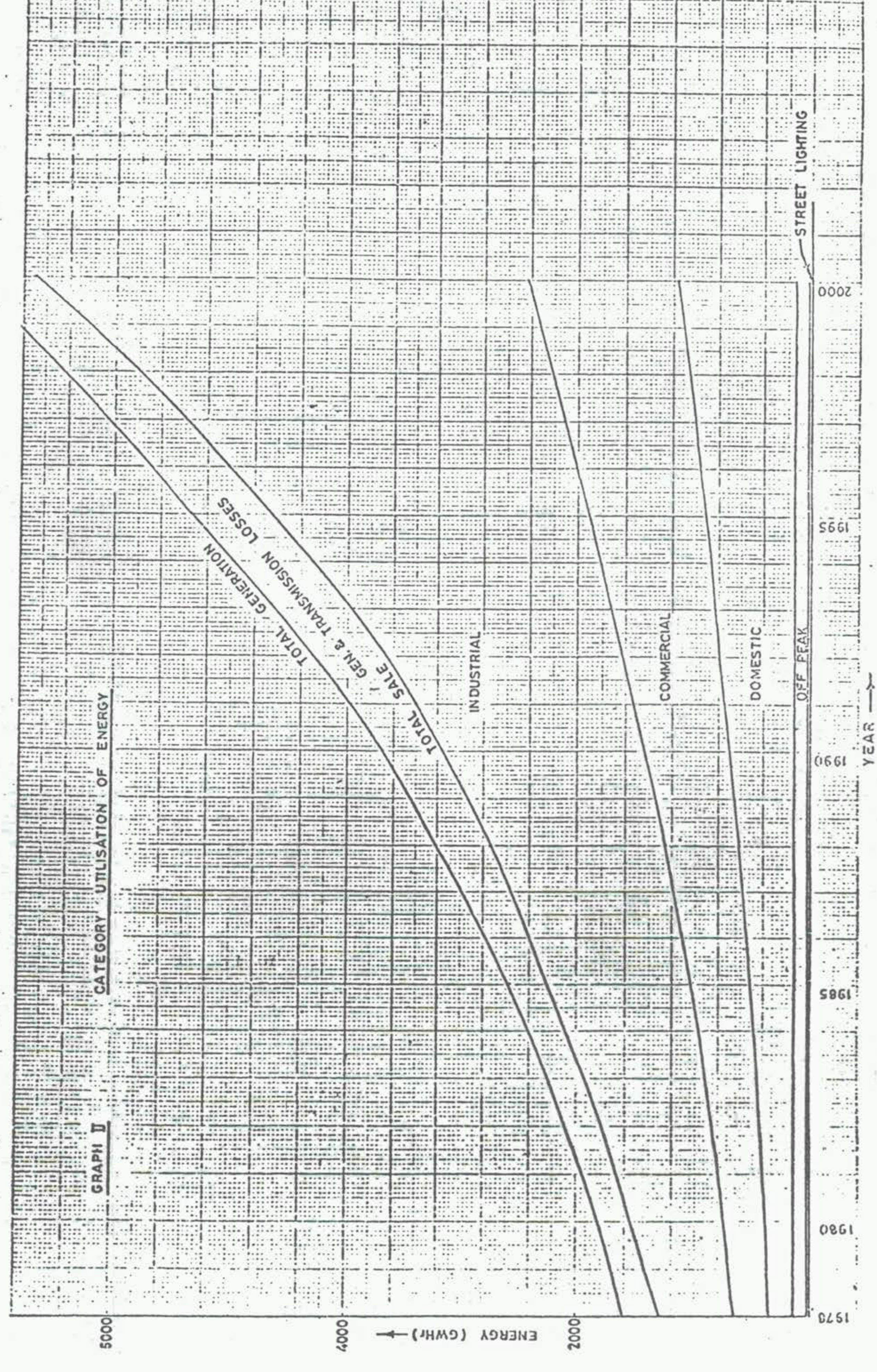
TABLE 11

COMPARATIVE PER UNIT COSTS OF TYPICAL RURAL ELECTRIFICATION SCHEMES

	YEARS OF OPERATION	CAPITAL COST (K£)	ANNUAL EXPENDITURE			ANNUAL REVENUE (K£)	ANNUAL LOSS (KWH)	UNITS SOLD (KWH)	MD (KW)	NUMBER OF CONSUMERS	COST PER KWH (CENTS)	REVENUE PER KWH (CENTS)
			CAPITAL CHARGES (K£)	O & M (K£)	TOTAL (K£)							
	RURAL ELECTRIFICATION SCHEMES (GOVT. FINANCED)											
LODWAR	2	118,884	12,779	21,836	34,615	6,654	28,246	116,416	30	43	600	114
NAROK	3	192,510	20,752	9,097	29,849	8,144	21,705	214,584	122	116	278	76
IRIANYI	1	78,310	7,640	7,596	15,236	8,866	6,370	276,367	138	122	110	64
	AMENITY SCHEMES (E A P & L FINANCED)											
CHOGORIA	7	48,852	4,692	14,017	18,709	16,896	1,813	452,000	172	281	83	75
GARISSA	7	80,129	6,318	43,606	49,924	30,047	19,877	686,677	210	493	145	87

GRAPH I DIFFERENT SOURCE OF ELECTRICAL ENERGY TO MEET THE DEMAND




GRAPH II
CATEGORY UTILISATION OF ENERGY
TOTAL GENERATION
GEN. & TRANSMISSION LOSSES
TOTAL SALE
INDUSTRIAL
COMMERCIAL
DOMESTIC
OFF PEAK
STREET LIGHTING
1970
1980
1985
1990
1995
2000
YEAR
5000
4000
2000
ENERGY (GWHr)

b) Isolated System:

Generation	Cents 113 per unit
Distribution	" 28 " "
Total	Cents 141 per unit

Average Cost of Energy in Different Areas:

Large Urban Areas	Cents 28 per unit
Small Urban Areas	Cents 38 per unit
Rural Connected	Cents 94 per unit
Rural Isolated	Cents 180 per unit

It is quite obvious from the above Table 2 that due to economy of scales and better utilization, the cost of electricity in urban areas is relatively cheaper than in rural areas.

Cost of providing electricity in rural areas is considerably more expensive due to long lines, few consumers and inefficient use of electricity for lighting and social amenities only. Table 3 gives the breakdown of capital, recurrent and unit cost of electricity in typical areas being funded under the rural electrification program. Depending on the areas and the number of consumers, cost of electricity in rural areas varies from cts -/83 per unit in a developed area like Chogoria to about Shs. 6/= per unit in a remote and undeveloped place like Lodwar. Average cost in an urban area like Nairobi is only cts -/30 per unit.

ROLE OF ELECTRICITY IN KENYA'S ECONOMY

Modern Sector:

Provided an industry is not far from the national grid, electricity will continue to provide the most efficient and economic means of motive power for the industry. It is expected, however, that for small scale industries, direct utilisation of windmills or micro hydro in some areas will be made and perhaps prove, in the long run, to be the most efficient nationally.

Consumers in commercial areas use electricity mainly for lighting, refrigeration, air-conditioning and some heating. It is a sad reflection on the ingenuity of some engineers and architects that in a place like Nairobi which enjoys such excellent climate throughout the year, that some of the larger buildings in the city centre are designed to use so much artificial lighting and air conditioning that it leads to waste of electricity. This is a tendency that must be curbed. The country must set standards for utilization of its scarce resources in a disciplined manner.

In the urban areas, electricity has little substitution to provide energy for lighting, refrigeration and radios at home. However, domestic cooking and water heating does have equally efficient substitutes and the use of gas cooking and solar heating should be encouraged. It is time that the country policy makers and planners should encourage investigation of use of solar energy for water heating. This calls for house plans which will substitute electrical water heaters with solar pannels.

Rural Sector:

Energy in rural areas is used primarily for:-

i) Basic sustainance (cooking, heating and lighting)

ii) Commerce and social amenities like hospitals and trading centres

iii) Economic development in pumping of water and irrigation, small-scale agro and village industries

iv) Transportation.

Because of high cost of supplying electricity to rural areas, it would be desirable if it is primarily used for development purposes. While the basic need for cooking and heating in the rural areas will largely be met by wood, charcoal and kerosene, electricity should play an important role to boost economic development and provide energy for some commercial and social amenities. Electricity in the rural areas has not as high a priority as supply of clean water, fuel, shelter and health centres. Furthermore, alternative sources of light and energy, though generally inferior, are nevertheless available in the remotest and poorest regions. It is important, therefore, that before an area is selected for electrification, proper economic cost/benefit analysis is carried out so that electricity when provided is used not merely to meet the social needs, but also to increase productivity and economic wealth in that area.

Rural electrification projects which have been financed by the Government in the past have been determined on social and political basis. It was first decided to supply all District Headquarters with power because they are centres of population. The second priority was given on the 20 development centres which were expected to generate economic development for areas surrounding. The least cost projects were given higher priorities within these guidelines. Cost analysis of a number of these schemes will bring home the enormous investment involved. A priority policy decision will have to be made as to whether investment in rural electrification is the best way of utilising these public funds. It must be remembered that the rural consumers are hampered by lack of capital to wire houses and buy electrical appliances and equipment. If cheaper electrical appliances and equipment were available, then electricity would play a more effective role as a source of energy in the rural areas.

FISCAL POLICY

Modern Sector:

There are generally two accepted principles of the formulation of energy decision:-

a) The so-called centralised economy based on 'need' or 'gaps',

b) Market economy based on supply and demand theory.

Centralised Economy:

In this concept, much thought and analysis is focused on energy need or gaps in energy supply, to be made good by the provision of particular fuels or by conservation. Such analysis concentrates on physical flows, and technologies are rated according to how much and how soon energy can be brought on stream to cover the shortfall and gaps. The concepts of supply, demand and prices in the sense of conventional market supply do not exist in gap analysis. The difficulty is that, excluding prices from the analysis does not exclude real costs from the real world. In reality, energy costs, whatever they are, and whoever incurs them, must somehow be paid by the economy.

Market Economy:

The other approach is to focus on energy prices as they operate in a market economy. In this view, there is no such thing as energy gap; supply is always equal to demand over any significant period of time except in the presence of price control and rationing. Some supplies may be less desirable because these are insecure such as diesel generation for industry or kerosene for lighting, or they may damage the environment like wood or charcoal for cooking, but in all cases the central question is the same. What price must we pay for energy and what premiums are we willing to pay to hold oil imports down or keep the environment clean? If a new technology is introduced like biogas for cooking or solar energy for heating or nuclear and geothermal for generation of electricity, it is the cost of the product in relation to price that will determine whether a new technology makes any contribution at all.

Fiscal Policy for Rural Electrification:

Fiscal policy for the rural areas should be based on central economy approach by setting up central pools of funds and setting up priorities on a regional basis. However, rural electrification should be evaluated and justified in the same way as other national projects like road transport, water, communications, schools and hospitals for rural development.

Fiscal Approach Suitable for Kenya's Economy:

In the context of energy supply in Kenya, both the above approaches have been applied with equal success. In the electricity supply industry, the central economy approach of meeting the demand of electricity is applied by using the least cost solution for generation mix. At the same time, market economy approach is applied with the consent and approval of the Government so that the tariff is raised from time to time to reflect the cost of generation of electricity and, at the same time, give an 8½% net return on assets employed to service the long term loans and generate part of the revenue to meet the future capital costs. This mixed approach has worked satisfactorily in the past and the industry has been largely self-supporting without direct subsidy from the Government and at the same time, contributing substantially to the Exchequer through sales tax, duty, corporate tax and dividend to the Government. It has also ascertained that those who exploit this national scarce resource contribute to national development.

INSTITUTIONALISATION OF THE POWER SECTOR

Modern Sector:

The public utility supply industry constitutes three main companies:-

a) Tana River Development Company, which is wholly Government-owned, is responsible for all hydro generation in the Seven Forks Area, Middle and Lower Tana.

b) Kenya Power Company, which is again wholly Government-owned, is responsible for the supply from Uganda, two small hydro stations on the Upper Tana and will also be responsible for all geothermal exploitation in the Olkaria and other areas.

These two Government-owned companies generate and sell power to the East African Power and Lighting Company Limited at ascertained cost, that is, cost of production of power, funds necessary to service lines owned by this company, plus maintenance costs.

c) The East African Power and Lighting Company is a private company with a 57% Government shareholding and is responsible for the entire distribution of electricity throughout the country under the Electric Power Act. It is also responsible for thermal stations in Mombasa, Nairobi and upcountry.

The above arrangement has worked satisfactorily, not only because there is a major Government participation in regulating the tariff and guaranteeing financing of larger projects, but also because it is commercially managed and has so far given relatively efficient service to its consumers at a price which reflects the cost of providing the service without any direct subsidy from the Exchequer. This has been the policy in the past but whether this should continue to be the policy could very well be looked into by our policy makers but whatever decisions are made, they should be made on the basis of economic cost benefits. Subsidy results in national waste.

Rural Electrification:

The Kenya Government finances uneconomic rural electrification schemes through the Rural Electrification Fund and the East African Power and Lighting Company provides 1% of its total revenue to meet the capital and operational losses in amenity schemes. The Rural Electrification Scheme is co-ordinated and administered by the Electricity Development Committee composed of representatives from the Ministry of Power and Communications, the Ministry of Finance and the EAPL. EAPL is the executing agency to implement the various projects initiated and approved by EDC.

While EAPL can remain the executing agency to implement the rural electrification programme, the Energy Department of the Ministry of Power and Communications should carry out the rural electrification programme as well as formulate and initiate total rural energy programme to embrace development of biogas, windmills, solar heating and micro hydro in rural areas and control the use of wood and charcoal. The Department should have permanent professional staff, engineers, economists and administrators to identify and evaluate projects, prepare feasibility and project reports, provide funds and hand over the projects to the executing agency.

Proposed Institutionalisation:

Due to the scarcity of our energy resources, and the need to develop new indigineous resources, ideally a central organisation like the "Ministry of Energy" should be created to look after the entire needs in the country in the modern and rural sector. This Ministry should formulate and initiate total energy programme to embrace the development of biogas, windmills, solar heating and micro-hydro in the rural areas; manage and control the supply of wood and charcoal; and intensify its efforts in the exploration of oil, geothermal and coal reserves. The Ministry should have full complement of permanent professional staff to plan the total energy programme.

CONCLUSION

The paper outlines the role of electricity in the modern and rural sectors of Kenya's economy. It analyses the peculiar dilemma which Kenya faces of having very limited primary energy resources, and therefore, having to depend on imported fuel for its energy needs and, at the same time, having limited financial resources to meet the energy bill. It suggests that there is no simple solution to the problem but that considerable progress can be made by understanding the energy problem in its right perspective and start developing and managing the indigeneous resources in Kenya with good pricing policy and proper Government controls. It suggests that perhaps the biggest challenge facing Kenya, as a result of this scarcity of energy resources, is to devise ingenious management techniques and create appropriate institutional machinery that will provide much needed co-ordination, and produce acceptable and efficient results.

FUTURE DEVELOPMENT POSSIBILITIES FOR KENYA AND THEIR ENERGY IMPLICATIONS

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SUMMARY

A range of alternative development strategies is hypothetically available to Kenya, with each strategy carrying different implications for future energy needs. There are, however, constraints on the actual freedom of policy-makers to depart radically from the pattern of development established in the 15 years since independence, especially in the medium-term. We have therefore used income and price-elasticities of demand for electricity and total energy consumption derived from historical series in order to make projections to 1985 and 2000.

The results of these projections vary according to assumptions made about the growth of the economy and the behaviour of prices. If, for example, the economy were to grow in 1974-85 at the annual rate of 6.3% (which is the target growth rate in the 1979-83 development plan) and if real prices were to remain unchanged, the total energy consumption would approximately double during that period. Projections to the year 2000 are even more sensitive to the chosen assumptions. They show increases in the consumption of electricity and energy petroleum products by 2000 of between 170% and 1060% above 1977 levels.

I - DEVELOPMENT STRATEGIES AND CONSTRAINTS

By a development strategy we mean an integrated package of policy measures, affecting major (or structural) economic variables and informed by some view or philosophy of the type of socio-economic system it is desired to create over the longer-term. It deals with large issues, sees economic policy as a whole, gives the decision-makers a sense of direction and provides a set of general principles upon which to base specific policy measures. Detailed policy actions are the 'tactics' which implement the strategy.

There is a theoretically wide range of strategy alternatives which may be considered by a country such as Kenya but we will limit ourselves to a brief statement of the most important alternatives within the context of the concerns of this workshop.

(1) The strategy most widely adopted within Africa in the years immediately after independence was one of import-substituting industrialisation. This placed emphasis on the development of a manufacturing sector producing goods for the home market which formerly had to be imported from the industrial nations. Such a strategy involved the provision of protection against competing imports, frequently the state participation in the ownership and operations of the new industries and the provision of the back-up infrastructure (including power supplies) necessary for the industrialization process. In terms of priorities and resource allocations, agriculture and exports were viewed as of

secondary importance.

To some extent this is a description of the strategy that has been pursued by Kenya. It has the further characteristic of utilising Western technologies and, therefore, of employing much capital relative to labour, and of requiring relatively large inputs of energy for its production processes. Although it substitutes local manufactures for foreign-made goods, it often fails to result in large net foreign exchange savings because of the inability of the industries created to take advantage of economies of large-scale production, and frequently heavy dependence on imported materials, spares and capital. There is today fairly wide-spread acceptance that, as a long-term strategy, import-substitution has some rather severe disadvantages and developing countries have increasingly sought after more satisfactory alternatives.

(2) One such is a strategy of export-led development. In some of the larger or more advanced developing countries this has taken the form of the promotion of manufactured exports and can thus be viewed simply as an alternative form of industrialization - producing mainly for world rather than domestic markets. To succeed in such an endeavour is, however, more difficult than import-subsitution, partly because of barriers against imports of manufactured goods from developing countries erected by the industrial nations; and partly because industries must be more efficient if they are to succeed in highly competitive world markets, than if they are simply supplying the home market and are protected from foreign competition.

In a country such as Kenya, however, an export-led strategy would be primarily agricultural (although it would be important to diversify into non-traditional export lines as well). Coffee, tea, pyrethrum, and meat - all Kenya's main commodity exports are agricultural, except for the special case of petroleum products, which are essentially re-exports of an imported commodity after refining. If the country's exports were to remain primarily agricultural, an export-led development would be more favourable to some parts of the rural areas (especially the Central and Eastern provinces). It would be less capital-intensive and more employment-creating. It would require smaller energy inputs than import-substitution. It would, however, stand in danger of neglecting the local food farmers and could result in a worsening of income inequalities within the rural economy.

(3) A third strategy could incorporate the promotion of exports but would be wider in scope. This is known as a strategy of redistribution through growth, or as a basic needs approach to development. (The economic literature identifies subtle differences between the two approaches just mentioned but for present purposes they can be treated as synonymous). In some degree, Kenya's Development Plan, 1974-78 incorporated a strategy of redistribution through growth. And the new 1979-83 plan (although it had not been published when this paper was prepared) is stated to be oriented to the satisfaction of the people's basic needs.

Since it is the government's stated approach to the development of the Kenyan economy, it is worth elaborating the redistribution through growth strategy a little more fully than the other two. Its main components are :

(A) SECTORAL PRIORITIES which particularly favour the development of smallholder agriculture and the 'informal sector' (which can be roughly defined as consisting of small-scale non-farming activities in the towns and rural areas). Most poverty is found among smallholders and the landless in rural areas. It is also common among the underemployed and unemployed of the towns. Smallholder agriculture and the informal sector are labour-intensive, so their development will both generate more employment and raise the productivities (and hence incomes) of those already working in them. Negatively, an only second-order priority is indicated for the expansion of the modern industrial sector (although it is likely to remain important) and for large-scale, plantation-type agricultural ventures.

(B) RURAL DEVELOPMENT is a related aspect of the strategy, aimed especially at raising standards in rural communities. It goes beyond the higher priority for smallholder agriculture mentioned in the previous paragraph by approaching the development of the rural economy in an integrated way - seeking to raise output but also the availability of social services and amenities. This involves the co-ordination of programmes for the improvement of agriculture, water, transport and so forth. It is often associated with the decentralisation of development planning activities. In some countries, land reform is an essential ingredient. The basic intention of this thrust of the strategy to reduce the large urban-rural disparities which are fundamental to the problems of poverty and unemployment.

(C) FACTORIAL PRIORITIES which favour labour-intensity and employment creation, and economise on the use of capital and foreign exchange. Employment creation programmes are likely to be crucial in assisting rural poverty groups without enough land, and the urban unemployed or underemployed. They are thus likely to be central to any successful attack on the poverty and employment problems. The adoption of more appropriate technologies is crucial to this aspect of the strategy.

(D) POPULATION RESTRAINT is another important aspect in countries, like Kenya, with rapidly expanding populations, because of the connections between poverty and family size, and between the growth of population and labour force.

(E) The strategy is selective in that it concentrates on measures to raise the living conditions of precisely identified POVERTY GROUPS. Poverty is by no means a uniform condition. Its nature differs between town and village and between different groups within each type of community. Thus, subsistence farmers can be differentiated from the rural landless, with the open urban unemployed and the urban 'working poor' as other separately identifiable groups. The incidence and nature of poverty is also likely to be affected by differing regional conditions, as in Kenya, where there are also large regional inequalities. And these groups will differ in the degree of their integration into the national economy and in their links with more well-to-do groups in society. Because of these varying circumstances, a given policy measure will affect poverty groups in differing ways, so precise knowledge of the nature of these groups is essential before we can accurately devise policies to help them.

(F) Implicit in the above is an aspect that should be made explicit: the strategy emphasises IMPROVED ACCESS of poverty groups to goods, services and capital assets provided by the state. Especial emphasis is placed on ensuring that poverty groups obtain better access to good education, health services, piped water and power; and that government capital formation in roads, housing, irrigation etc. should be designed to reach the poor. Education is seen as of especial importance in this context.

Rather obviously, such a strategy would generate a smaller increase in demand for energy, for any given rate of growth of the economy, than a strategy of industrialization. Thus, if the growth path followed by Kenya in the future is of this type, it will be a factor limiting the demand for energy as a productive input when compared with the import-substitution of the later 1960s and earlier 1970s.

But is the growth path likely to lead in the direction of redistribution through growth, as advocated in the country's development plans? It is important at this point to recognise the existence of some severe constraints on the country's ability to change course in the desired direction.

First, there exist strongly entrenched interest groups, who have benefitted from past policies and can be relied upon to oppose radical changes in the future. Many inefficient industries have been created, in textiles, in vehicle assembly, in engineering, which would suffer from serious moves towards redistribution through growth. Although many of these are foreign-owned, the government itself (or prominent politicians and civil servants) often has a stake in them and this makes it more reluctant to take measures which may reduce the profitability of its own investments. To put the point in a rather different way, there is a gap between the public rhetoric about satisfying basic needs and actual day-to-day policy decisions (Killick, 1976).

This rhetoric-reality gap has, for example, shown itself in the contrasts between the government's past sympathetic noises about the desirability of fostering the informal sector and its failure to implement this stated objective (or even to prevent the Nairobi City Council from destroying part of the informal sector). The same is true of various general statements about the desirability of land reform.

A second difficulty is that the notion of a development strategy is a long-term one. It therefore requires that decision-makers have sufficiently long time-horizons, and that there is enough continuity in policy, for the notion of a strategy to make sense. In reality, of course, many decisions are short-run and piecemeal responses to unforeseen emergencies. And the uncertainties of political life do not make for a steady concern with the consistent pursuit of some distant vision of the type of society it is desired to create.

Third, resource shortages limit planners' abilities to achieve what they desire. In the present context, one of the most serious of these deficiencies is shortages of knowledge. We simply do not know enough about the nature and extent of poverty groups; about how different groups and economic activities interact with one another; about how the economy will respond to given policy changes, to be able to redistribute through growth except in a hit-or-miss fashion.

Nor do we have the expertise to do so. There is widespread agreement that the content and quality of the educational system requires substantial reform if it is to meet mass needs and to cease to cater primarily for an intellectual elite (Court and Ghai, 1974). But it is doubtful whether, even if the will were there, the trained personnel could become available more than gradually to execute such reforms.

Similarly with agriculture. A greater emphasis on the relatively underprivileged smallholders would probably require considerably more expert agriculturalists and extension workers than are currently available.

Again, the policy instruments available to government in the pursuit of their objectives are often weak in relation to the gravity of the problems to which they are addressed. Two examples: The development and adoption of more appropriate technologies (technologies which are more labour-intensive, smaller-scale, and make greater use of locally available resources than Western technologies) is of crucial importance to redistribution through growth. But it is not clear that governments can act effectively in this area of research and development. Again, there would be wide agreement among economists that Kenya's rapid population growth (at 3.5% p.a., one of the fastest in the world) is an obstacle to economic development and that there is therefore a strong case for government policies to reduce this growth. But here too, it is not evident that government can act effectively in this highly sensitive area. It would certainly be unrealistic to expect major reductions except over the longer-run.

Because of constraints of this kind, the revealed power of development planners to exercise a decisive influence on the course of development is slight. There is today a disillusionment with the potentialities of planning and there are a number of studies suggesting that many development plans have low success rates. One study of planning in Africa concluded that the actual growth of the economies was largely determined by historical momentum and by the influence of market forces, and that plans are rather powerless to modify these outcomes (Shen, 1975, 1977). A recent study of plan implementation in Kenya similarly found rather low success rates in project implementation and that, although there were some successes, a good many of the policy intentions in the 1974-78 plan were ignored practice (Killick and Kinyua, 1979).

For the purposes of this workshop, the main inference of this analysis is that we are unlikely to see dramatic changes in the way the economy develops over the next several years, although there could be larger changes in the longer-run. The past is likely to serve as an approximate model for the medium-term future. It is therefore legitimate to gauge the probable future demand for energy from an examination of past trends, to which we now turn.

II. <u>ENERGY DEMAND IN KENYA: PAST AND FUTURE</u>

Table 1 shows the historical patterns of demand for commercial energy resources in Kenya, beginning almost a decade before the country became independent.

Table 1: Demand Patterns for Commercial Energy in Kenya, Selected years. (1000 tonnes of Coal Equivalent).

Year	Total Electricity Sales	Total Consumption of energy Petroleum Products	Consumption of Total Commercial Energy
1955	74	615	689
1960	128	718	846
1965	165	734	899
1970	245	903	1,148
1972	302	1,121	1,423
1974	351	1,399	1,750
1975	381	1,700	2,081
1976	411	1,725	2,136
1977	457	1,784	2,241

Sources: (1) World Energy Supplies, 1950-1974
(2) Kenya Economic Surveys
(3) Statistics of Energy and Power; Central Bureau of Statistics.
(4) Kenya Statistical Abstracts

From this table, it is clear that petroleum fuels constitute the major source of commercial energy in Kenya, comprising over 80% of total commercial energy demands throughout this period. Petroleum has not lost this relatively important position in the energy picture in Kenya despite the rapid increase in total electricity sales in the country. For example, although the latter sales have increased over six times between 1955 and 1977 consumption of petroleum fuels has increased by only about three times in the same period. The relative share of petroleum fuels in total commercial energy demand decreased only slightly, from about 89% in 1955 to about 80% in 1977, so that the relative share of electricity in total commercial energy demand rose from 11% in 1955 to 20% in 1977.

This reveals that Kenya has been relying heavily on petroleum as a source of commercial energy. This position is not likely to change soon because of two major reasons; first, most of the petroleum fuels are used in the industrial and transportation sectors where there exist no economically viable close substitutes for these fuels today or in the near future; second, Kenya's potential for the production and supply of electricity is not large. A few years back Hans Amann (1969) estimated the potential energy of the Tana River to be about 15,350 million kwh/y of which only about 2,700 million kwh can be usefully exploited after allowing for upstream detractions for irrigation, spillage, head which cannot be developed economically, and other losses. Thus the share of electricity in the total commercial energy demand cannot be increased substantially from the current level. Furthermore, should the production of thermal electricity be increased this would increase the demand for those petroleum fuels used in its generation.

Table 2: Net Sales of Petroleum Fuels, by Consumer Category in Kenya, Selected Years (in 1000 tonnes)

ITEM DISPOSITION	1968	1971	1974	1977
1. Agriculture	35.1	65.7	57.6	64.0
2. Road transport	128.8	276.4	336.5	428.0
3. Rail transport	351.9	239.4	91.4	89.8
4. Marine	157.5	115.4	196.3	132.4
5. Aviation	50.7	113.1	275.4	324.2
6. Power generation	57.5	88.5	94.4	124.4
7. Industrial and Commercial	87.2	187.7	295.8	360.7
8. Government	30.2	53.5	40.8	48.7
9. Unallocated estimate	9.0	-71.7	-162.0	-69.4
10. TOTAL SALES	908.0	1,068.1	1,226.2	1,502.8

Sources: (1) E.A. Statistics of Energy and Power, 1966 - 1973.
(2) C.B.S. unpublished working papers.

Table 2 reveals interesting patterns of change in sectoral demands for petroleum fuels in Kenya over the period under consideration. The amount of petroleum fuels used in agriculture almost doubled, from 35,000 tonnes in 1968 to 64,000 tonnes in 1977. Also, the amount of petroleum fuels used in power generation doubled in this period.

Phenomenal increases in the amounts of petroleum fuels used are recorded in road transport, aviation, and in the industrial and commercial sectors. The amount used more than tripled in road transport between 1968 and 1977, reflecting a rapid expansion of this sector of the economy. Meanwhile in 1977 aviation consumed more than six times more petroleum fuels than in 1968, reflecting a very rapid expansion of this sector to cater for the growing tourist industry, while the industrial and commercial sectors consumed more than four times the amount in 1977 that they did in 1968, which is a direct result of the kind of industrial growth that took place in Kenya after Independence.

Spectacular increases in electricity sales were also recorded in the commercial and industrial sectors. Sales to commercial users increased almost twelve times between 1957 and 1976, whereas sales to the industrial users increased by about five times in this period. The 'special contracts' category recorded a sales increase of about eight times by 1976 over what it was in 1957. Recently, high rates of increase of electricity sales have continued in the domestic, water-heating, industrial and commercial categories of uses. This is possibly a result of increased affluence, especially on the part of urban dwellers who have tended to use more electric power for domestic purposes and for heating water, and also because of the rapid economic expansion that Kenya has experienced since Independence, especially the rapid industrialization and the attendant expansion of the commercial sector of the economy. It would seem that electricity sales to the industrial and commercial sectors will continue to increase relatively rapidly in the near future, other things remaining equal.

Having surveyed the changes in demand for energy we turn briefly to explain sources of energy supplies.

Kenya is a net importer of commercial energy, both electric power and petroleum fuels. In fact all petroleum fuels are either imported directly or derived from imported crude oil which is refined at Mombasa. Since Independence the Government has initiated projects aimed at reducing Kenya's dependence on imported electric power and, although this has almost been achieved, some power continues to be imported from Uganda.

Imports of crude oil have increased rapidly since Kenya became independent. Beginning 1964, the first full year of operations for the East African Oil Refinary (EAOR) at Mombasa, we see that those imports rose from about 1.5 million tonnes to about 2.8 million tonnes in 1975, as shown in Table 3.

Table 3: Imports of Crude Oil, Kenya, Selected Years.

Year	Quantity of Imports ('000 tonnes)	Value of Imports (K£ '000) At Current Prices	Value of Imports (K£'000) At Constant 1964 Prices
1964	1506.1	7,274.0	7,274.0
1965	1851.2	9,070.3	9,163.8
1970	2205.6	11,022.8	10,304.6
1972	2499.2	14,586.7	12,311.5
1973	2716.0	17,557.4	14,192.4
1974	2807.7	67,027.0	45,408.2
1975	2825.0	86,822.4	51,812.6

Sources: (1) Kenya Statistical Abstracts
(2) Kenya Economic Surveys
(3) Project estimates.

From Table 3 we note that whereas crude oil imports into Kenya by quantity almost doubled between 1964 and 1975, the import bill from this one commodity increased almost twelve times in this time period! This comes about as a result of the rapid increases in crude oil prices, especially after the oil crisis of 1973. Noteworthy is the striking jump in the value of crude oil imports between 1973 and 1974. In 1973 this value was 2.41 times what it was in 1964, while one year later, in 1974, it was 9.21 times the 1964 figure!

In early 1979 the impact of the proposed 15% price rise by OPEC is already being felt in the Kenya balance of payments. Indeed, as a result of the political turmoil in Iran and the greatly reduced output from its oil fields, the overall price rise to Kenya is likely to be far in excess of 15%, imposing severe strains on the balance of payments. The result could be that there will need to be curtailments in the development projects envisaged by the government during the current 5 year planning period.

To illustrate the dimensions of the problem we should recall that the transportation sector - including road, rail, marine and aviation - consumes approximately 70% of all petroleum fuel sales. All of the development strategies discussed earlier necessarily imply continued rapid expansion of this important sector and, without any major substitute fuels, Kenya's freedom to pursue the development strategy of its choice is severely constrained by external factors impinging on her foreign exchange position.

In order to project alternative energy scenarios for the future it is necessary to estimate the response of energy demand to a change in (1) GDP or incomes of households and firms and (2) price of energy and of its various components. These responses are what economists call the 'income elasticity' and the 'price elasticity' of demand, respectively. Thus, if a 1 per cent increase in GDP should lead to a 2 per cent rise in the annual consumption of energy, we would say the income elasticity of demand for energy, assuming the price of energy is unchanged, would be + 2. Analogously, if a 1 per cent rise in the price of energy should result in a 1 per cent fall in energy consumption, assuming GDP is unchanged, then the price elasticity would be - 1.

When we make energy demand a function of output in the economy we should be clear to note that the elasticity derived will be in turn a function of time. Why should the output elasticity of energy demand change over time?

There are a number of reasons why the output elasticity will change:

(a) If some fuels are used more efficiently than others, for example, due to differences in the efficiencies of energy consuming equipment, there may be a shift from less efficiently used fuels to the more efficient ones. In this case energy consumption per unit of output will fall.

(b) Technological progress is often responsible for the introduction of more efficient (energy saving) equipment for all fuels. This is particularly true in production where the tendency is often to substitute capital for labour. In these circumstances we would observe a reduction of energy use per unit of output. On the other hand if Kenya should hold back the introduction of energy saving technologies which are embodied in the latest vintages of capital equipment, in order to make output more labour intensive, the energy intensity of output would be unlikely to fall.

(c) As the economy grows and the relative shares of the industrial, agricultural and service sectors change, energy consumption per unit of output will vary because some sectors are more energy intensive than others. For example, a shift towards such industries as iron and steel, cement, aluminium and petrochemicals would necessarily lead to a rise in the energy intensity of output, because these industries are large-scale users of fuels. The likely direction of industrialization in the longer-term in Kenya is towards such energy-intensive industries.

(d) An increase in the relative importance of secondary electricity at the expense of other fuels would tend to raise energy consumption per unit of output because of the relatively low efficiency of conversion of primary fuels to electricity.

(e) 'Save energy' compaigns, which lead the population to be conscious about not wasting fuel, backed up, for example, by the imposition and enforcement of speed limits and driving bans on certain days, would reduce the energy consumption per unit of GDP.

These factors are likely to cause the elasticity of energy demand with respect to output to vary over time and to differ from unity at any point in time. While factors (a) and (e) are likely to be energy saving and factors (d) might well raise this elasticity, factors (b) and (c) might cause the elasticity to change in either direction. These factors might not be changing autonomously but because of government policies or because of underlying price changes.

While we cannot easily identify the effects of all the factors listed we would expect price in addition to GDP to be an important variable in the determination of fuel demand.

Over the longer run we would expect that the elasticity of energy consumption with respect to changes in GDP to rise. As structural changes and industrialization take place in Kenya, as the manufacturing and transport sectors continue to increase their shares of national product, the energy intensity of output will increase. Kenya's per capita consumption of energy is relatively low but can be expected to rise as development proceeds and the economy produces more sophisticated goods, which require wider use of energy - consuming capital equipment.

Using time-series data for the various sectors of the Kenya economy, income and price elasticities of demand for energy were estimated. The results indicate that as the output of goods and services increases in the economy, as measured by the growth in GDP, energy consumption increases in almost exactly the same proportion. And for the major components of electricity and petroleum fuel demands, price appears as a significant variable, although the estimated elasticity is much smaller than for income.

Forecasts for Year 1985:

Electricity

We have estimated that the estimated GDP elasticity is 1.01 and the price elasticity is - 0.564 for the total demand for electricity. Therefore a 1 per cent per annum growth in GDP, with prices constant, would give rise to a 1.01 per cent per annum growth in electricity demand. A 1 per cent per annum rise in the real (1964) price of electricity, with GDP constant, would lead to a 0.564 per cent per annum fall in the demand for electricity.

In projecting electricity consumption to 1985 we have assumed possible annual GDP real growth rates of 3%, 5%, 8.3% (which is the planned growth rate in the 1979 - 1983 Development plan) and a high of 8%. In addition, we have made demand projections under alternative electricity price assumptions. We have considered an annual price fall of 5%, a zero price change and an annual price rise of 5%. These price changes are denominated in the prices of our base year 1964. Therefore a 20 per cent increase in average prices in, say, 1980 would imply a 20 per cent rate of inflation and this would necessitate a rise in the nominal price of electricity also of 20 per cent in order to keep the real price of electricity unchanged. Alternatively, a 20 per cent rate of inflation together with a 15 per cent rise in the nominal price of electricity would imply a 5 per cent fall in the real price of electricity.

We see from Table 4 that if the 1979-83 Development plan's growth target of 6.3 per cent were achieved through 1985, and the real (1974) price of electricity were unchanged (that is, nominal price increases just matched the overall rate of inflation) then electricity consumption in 1985 would be 1,975,280 thousand Kwh. This would represent a growth of 64 per cent over the 1977 level of consumption.

On the other hand, consumption would be even greater in 1985 if the 6.3 per cent annual growth of real GDP were accompanied by a 5 per cent annual fall in the real price of electricity. In that case consumption would be 2,280,453 thousand Kwh, the additional demand being induced by the price fall. Alternatively, annual price rise of 5 per cent would induce conservation of electricity and demand would be lower at 1,870,097 Kwh.

Table 4: Percentage Change in Projected 1985 Electricity Consumption over 1977 Level, under Alternative Assumptions about Annual Growth Rates in Real GDP and the Price of Electricity

		Alternative GDP Annual Growth			
		3%	5%	6.3%	8%
	-5%	52.5	74.2	89.8	111.8
Alternative price changes	0	27.1	48.8	64.4	86.4
	+5%	11.7	23.4	39.0	61.0

We see from Table 4 that the most rapid growth in electricity demand by 1985 would occur if the economy grew at 8 per cent per annum and the price of electricity fell by 5 per cent per year. Under these conditions projected demand in 1985 would be 112% greater than in 1977.

Total Energy and Energy Products

In terms of total energy consumption, measured in tonnes of coal equivalent, we found the GDP elasticity to be 1.001 while we had no satisfactory index of the price of total energy. Under the previous growth scenaries, therefore, we could expect growth in total consumption of energy to move in unison with the overall real growth of the economy. The projected increases in total energy consumption are given in Table 5.

Table 5: Projected Increases in Total Energy Consumption, in Millions of Metric Tonnes of Coal Equivalent and Percentage Changes in Energy Consumption between 1974 and 1985.

Assumed Growth in GDP	1985 Total Energy Consumption in Million Tonnes of Coal Equivalent	Percentage Increase 1974 - 1985
3%	3.152	38
5%	3.899	71
6.3%	4.460	96
8%	5.310	133

Note: The 1974 level of consumption was 2.279 million metric tonnes of coal equivalent.

If the target growth rate of the new Development Plan should be realized, on average, over the 1974 - 1985 period, then we would predict a rise of 96 per cent in Kenya's consumption of total energy during this 11 year period.

Given that the share of electricity in total energy demand is likely to remain roughly constant, since the GDP elasticities are slightly over one for electricity, petroleum products and total energy, then we can expect the domestic consumption of crude oil to rise at roughly the same rate as that of total energy demand.

The value of imports in constant prices rose at a cumulative annual rate of 7.9% between 1968 and 1976. Therefore the share of crude oil in the total import bill will maintain its present level if there are no real increases in the price of oil. If the latter should rise, the relative importance of crude oil in the import bill will continue to grow, with serious consequences for the balance of payments. This latter possibility cannot be ruled out given the impredictable nature of the pricing policies of the OPEC cartel.

Forecasts for Year 2000

Over the longer run Kenya's energy - intensity of output or elasticity of demand for energy with respect to output or GDP, is very likely to increase. Currently, by world standards, per capita energy consumption is low and can be expected to rise. This is especially so as the pace of the type of industrization pursued to the present quickens and more energy - intensive industries are established. Therefore, to make projections of energy to the year 2000 is an extremely hazardous exercise. The direction of industrial development policy remains an unknown so we can only make intelligent guesses as to the likely changes in the structural make up of the economy over the next 20 years.

We would expect the share in GDP of the manufacturing and transport sectors to continue to increase with the result that the elasticity of demand for energy with respect to income will increase, perhaps by as much as 25%. At this stage it is impossible to make predictions as to the likely alternative commercial supplies of energy so we make no estimates of the likely changes in the price elasticity of demand for energy and its components.

In Table 6 we have made tentative estimates of the likely demand for total energy and electricity by the year 2000 under the assumptions that the income elasticities of demand rise by a maximum of 25%. Actual levels of demand will likely lie somewhere within the range between zero change and a 25% rise in this elasticity.

Table 6: Projected Consumption of Total Energy for the year 2000 Under Alternative Growth Scenarios for the Years 1985 to 2000.

Alternative GDP annual Growth	Total Energy Consumption Elasticity Change	
%	0%	25%
2	6.003	6.454
4	8.019	9.272
6	10.686	13.237
8	14.188	18.638
10	18.638	26.051

(Consumption is measured in millions of tonnes of coal equivalent).

In Table 7 we have converted projected electricity consumption to million tonnes of coal equivalent, and assumed that the remainder of total energy demand will be fulfilled by energy petroleum products.

Table 7: Consumption of Electricity and Energy Petroleum Products for the Year 2000 Under Alternative Growth Scenarios for the Years 1985 to 2000.

Alternative GDP Growth Rates		Energy Consumption in million tonnes of C.E. Elasticity Changes	
		0%	25%
2%	Electricity	1.009	1.100
	Petroleum Products	4.994	5.354
4%	Electricity	1.350	1.581
	Petroleum Products	6.669	7.791
6%	Electricity	1.796	2.257
	Petroleum Products	8.890	10.980
8%	Electricity	2.409	3.176
	Petroleum Products	11.729	15.462
10%	Electricity	3.176	4.440
	Petroleum Products	15.462	21.611

Our estimate of total commercial energy consumption in Kenya in 1977 is 2.241 million tonnes of coal equivalent, 0.457 million tonnes arising from the electricity sector and 1.784 million tonnes from energy petroleum products. We are projecting for the year 2000 an increase in total demand, at a minimum of 2% annual growth in GDP from 1985 and no change in the GDP elasticity, of 170% over the 1977 level. At a maximum, with a 10% annual growth in the economy from 1985 and a 25% increase in the GDP elasticity, total consumption would have risen by 1060% in the year 2000 over the 1977 level. No doubt the actual rise will lie somewhere within this range.

Major technological innovations may well take place during the last two decades of this century that could replace oil-based energy products with agricultural-based processed fuels. For example, the processing of molasses in order to manufacture a form of motor fuel appears as a viable commercial venture.

Alternative sources of energy such as wind power, solar energy, tidal wave power and biogas may have been developed to an extent to have partly replaced the dependence on oil. Electricity will soon be generated in small quantities from a geothermal source in the Rift Valley while a switch in the longer run to nuclear reactors would change the country's dependence on imported oil to some extent to a dependence on imported uranium.

Therefore, assuming greater relative use is made of Kenya's domestic hydro-electricity resources to substitute for petroleum-based products, domestic oil requirements (excluding those for exports of refined fuels) would lie between 8.4 and 11.8 million tonnes of crude oil in 2000. The import cost, at a price of K£37.5 per tonne in 1976 prices, would lie between K£34 million and K£443 million, an enormous increase over the cost of oil imports for domestic use of perhaps K£50 million in 1976.

REFERENCES

Amann, H. : Energy Supply and Economic Development in East Africa Munich; Weltforum Verlag; (1969).

Court, D. and Ghai, D. (eds.). Education, Society and Development: New Perspectives from Kenya, Nairobi, Oxford U.P., (1974).

Killick, T. : 'Strengthening Kenya's development strategy: opportunities and constraints', IDS Discussion Paper No. 239, University of Nairobi, October (1976).

Killick, T. and Kinyua, J.K. : 'Development Plan implementation in Kenya' (mimeo), University of Nairobi, (1979).

Shen, E. : Eastern Africa Economic Review, June 1975; and Journal of Development Studies, July 1977.

NEW VILLAGE USES OF RENEWABLE ENERGY SOURCES

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Summary

The goal of improving the physical quality of life is dependent upon finding substitutes for human energy at the village level. We see no prospects of meeting such a large energy requirement from conventional sources such as petroleum, nuclear, coal or major hydro. In some instances (e.g., Zaire or India) there may be enough hydroelectricity or coal but the problems of distributing the power to the distant countryside have proven to be overwhelming. Three factors make solar energy appear to be promising enough to give it a thorough test. First, solar energy is plentiful. There will be no shortage of primary energy in the combined potential of direct sunshine, photosynthesis, running water and wind. Second, it is already well distributed to the villages. There is no problem of transmission and distribution lines. Third, the technology to make use of this primary energy, although very imperfect and high priced, is progressing rapidly both in performance and costs. We do not know that solar energy will prove to be practical for village use, but it is sufficiently promising to warrant a careful test. If the widespread use of modern machinery becomes possible as a result of making energy available, the residential attractiveness of villages will improve and the quality of life for this majority of the world's people will be enriched. Thus a great deal is dependent upon the outcome of the next few years' tests of solar energy in the villages of the developing nations.

I. Current Energy Use in Developing Countries

There are three characteristics of the energy regimes in the Third World: (1) not much modern energy is used, (2) very little of that amount is used in rural villages and farms, but (3) a great deal of traditional energy is used—especially in rural areas.

A. Not Much Modern Energy is Used

There are about 2.4 billion people in the developing countries excluding China. About 2 billion of these people live in areas without electricity. This includes virtually all of the rural people and a number of people in urban slums as well.

Moreover, the bulk of the people living in rural areas at some distance from cities are not likely to be reached by the electrical grids for the foreseeable future.

The following table summarizes how much less energy is used in selected developing countries than in the United States:

Ratio of Energy Used in The United States Compared to (Per Capita, 1974)

Nepal	957 to one	India	57 to one
Burundi	883 to one	South Korea	12 to one
Upper Volta	820 to one		
Mali	478 to one		
Bangladesh	380 to one		

(Source: U.N. Statistical Series J. for 1976).

B. Most Modern Energy Use Is Concentrated in Urban Areas

As noted above, almost all electricity is used in urban areas. Other common "modern" forms of energy consist of petroleum driven engines, and industrial heat supplied by electricity, coal or petroleum. The latter (industrial heat) is confined almost exclusively to urban use. Trains, trucks and buses travel to rural areas but most vehicular travel is in urban areas. In many rural villages the only contact with modern energy may be a diesel driven pump or generator which lights a few commercial or public buildings and the trucks and buses that pass through. Although we have no comprehensive data on the share of modern energy consumed in urban areas, Brookhaven estimates from its work in Mexico that a resident migrating from the countryside into the city becomes ten times as energy intensive. (1) A.K.N. Reddy estimates that in India the ratio between the rich urban and the poorest 60% of the people (mostly rural) is from 4.3 to 8.6 to one. (2)

C. Much Traditional Energy Is Used In Rural Areas

Farmers and villagers use a great deal of crop residue, charcoal and cattle dung as fuel for cooking, crop or meat drying and space heating. In addition they use much animal traction in tilling the land and harvesting crops. In fact, one source estimates that farmers in developing countries use more energy per unit of crop produced than a U.S. farmer: (see Table 1).

But the story changes dramatically if one considers only fossil fuel energy in farming. The U.S. farmer uses from four to ten times as much fossil energy per unit of protein output as a farmer in the Third World, as is shown in Table 2.

Table 2. Comparison of Fossil Energy Inputs for Corn, Rice and Wheat.

(K Cal of Fossil Energy Input Per K Cal of Protein Output)

	United States	Developing Country
Rice	10.1	1.31 (Philippines)
Corn	3.63	.08 (Mexico)
Wheat	3.44	.65 (India)

Table 1. Energy Use Per Hectare in Rice Production in Various Countries Reproduced from Makhijani (3).

Country	Installed horse-power hp per ha[c] farm machines and draft animals[d] only	Energy for farm operations million Btu per ha[e]	Energy for irrigation and nitrogen fertilizers manufacture million Btu per ha	Total Energy input per ha million Btu	Rice yield kg/ha	Energy intensity million Btu per ton of rice
India	0.7	20	6.5	26.5	1,400	19
China	0.7	20	12	32	3,000	10.7
Taiwan	0.5	10	22	32	4,000	8
Japan	1.6	10	25	35	5,600	6.2
U.S.A.	1.5	7	25	32	5,100	6.3

[a]We have chosen to compare a single grain (rice) since total grain production not only depends on seed variety, soil quality, etc., but also on the mix of grains grown. Comparing a single grain, therefore, gives a better comparison of the energy intensity of various farming methods.

[b]Installed horsepower and energy use are based on national average energy use in agriculture. The numbers in this table are very approximate.

[c]For India and China about 20 percent of the installed horsepower is in tractors; for Taiwan 50 percent; for Japan 90 percent; for the U.S. 100 percent.

[d]We assume that one draft animal (ox, horse, mule) is approximately equal to $\frac{1}{2}$ horsepower. This implies a draft animal of about 250 kg[3]. For lack of data, it is assumed that draft animal weight is about the same in all poor countries. Since a bullock or horse weighing 250 kg is rather small animal, this assumption may give rise to an underestimate of installed horsepower for some countries (e.g. Taiwan). It is assumed that 75 per cent of the energy output of the draft animals is used on farms, the other 25 percent being used for transportation, pumping domestic water, and similar nonfarm activities (which are excluded from the calculations). Installed horsepower numbers include tractors, but exclude irrigation equipement, trucks, and autos on farms.

Annual energy input per draft animal is assumed to be 25 million Btu. Tractor fuel input 7 million Btu/ha/yr for fully mechanized farms (U.S. data).

[e]The energy for irrigation varies according to the irrigation method, terrain, rainfall, water table depth, etc. For the purposes of comparison we have used 15 million Btu of energy input (3 million Btu of useful work) per

irrigated hectare per crop. Thus in India, about 40 percent of the rice-producing land is irrigated, so that the irrigation energy input per hectare of rice-producing land is taken as $0.4 \times 15 \times 10^6$ Btu or 6 million Btu. The energy input for chemical nitrogen fertilizer manufacture is about 75 million Btu per metric ton of nitrogen. No energy cost is assigned to the preparation of organic fetilizer. The energy requirements for potassium and phosphorous are small compared to those for nitrogen fertilizers.

II. The Connection Between Energy and Development

The effort to improve human material wellbeing over the past many millenia has consisted in major part of finding and applying substitutes for human energy. Some of these substitutes have been sources of energy completely separate from the human body such as fire, wind, sun, draft animals, and flowing water. Others have been tools to enhance the power of human muscles such as wheels, hoes, levers, and gears. One respected authority, Professor Marion J. Levy, has defined the whole of modernization in terms of using "inanimate sources of power and (...) tools to multiply the effect of effort," (5). That definition goes further than this paper, which limits its inquiry to economic development. Moreoever, we recognize that scientific knowledge has contributed to economic development through better seeds, fertilizers, and a host of other inputs which are not substitutes for nor extensions of human energy. Nevertheless the pervasive transformations that have occurred as humans evolved from primitive hunters and gatherers to twentieth century urbanites are largely the result of finding substitutes for and supplements to human muscular energy, or, since the computer age, human mental energy.

Most of the energy used in rural areas is for cooking. A recent workshop directed by David Pimentel (6) concluded that from 60 to 90% of the energy in rural areas of developing countries is used in the food system, of which cooking accounts for 60%. The energy for such cooking comes almost entirely from organic sources such as wood, crop residues and dung.

Most village tasks are done with human or animal muscles. This is true of soil preparation, planting, tilling, harvesting, threshing, grinding, pumping, hauling crops or water and gathering wood, dung or crop residues for cooking. Aside from the sheer arduousness of these physical burdens this condition inhibits development in five ways. First, — recognizing the great variations among ethnic groups — for a substantial number of people there is an important labour shortage at critical times of the crop cycle. "Labour bottlenecks at one or more stages of the annual cycle of cultivation are a very obvious feature of peasant agriculture..." (7). This reduces the extent of acreage cultivated or the output harvested per acre or both. Second, goods are transported by foot or by animal power which puts a low ceiling on the extent of trade. Without much trade, villagers are limited to the rather low level of material well-being that is typically provided by a subsistence economy. Third, most villagers are condemned to darkness after the sun has gone down which inhibits formal education. Fourth, villagers are confined to water hauled from a nearby stream or open well which is inadequate for irrigation and may perpetuate diseases. Finally, they cook with wood, dung or crop residues with the result that the land is progressively being devegetated, drained of nutrients and eroded. Hence whenever a village must rely chiefly on traditional energy it is likely that the residents of that village have a low income and a low physical quality of life. Unfortunately this is true of most rural people in the developing countries. Since rural people make up nearly half of the people in Latin America, 78 percent in Asia and 81 percent in Africa, this is not an unimportant problem. Of course some of these same factors apply to the urban poor people as well. In fact many well established villagers are better off than people in urban slums.

III. Conventional Sources of Modern Energy

What are the chief conventional sources of the energy for development?

A. Petroleum

First and most important in the short run is petroleum. Although relatively little petroleum is used in Third World villages, almost all modern energy in the villages now is petroleum based and everywhere one looks in the rural Third World, plans are being laid to start down a petroleum based energy path. Kerosene is being used for lighting, diesel engines for electricity generation, pumping and grinding, and gasoline motors for transportation or farm tasks. The problem with petroleum is clear and inescapable: these countries are already having trouble paying for oil for their modern sector and many will not be able to pay for extending it to rural areas; but even if they had some way of financing such oil costs they would be establishing an obsolescing economic infrastructure—one they will be compelled to begin dismantling before the end of the century as physical limits to the availability of oil begin to be felt.

B. Nuclear

The smallest nuclear generators now commercially available are 600 megawatts and, for economic reasons, industry strongly favours increasing the size. Even the 600 mw generator is too large to be reliable for the power grids of all but a handful of developing countries. For this reason alone, quite apart from the many economic, environmental and security problems that have been raised, nuclear energy does not now appear to be a promising energy source for most developing countries.

C. Other Site Specific Sources

Coal, major hydroelectric, and geothermal energy all have important potential for selected countries, but all share the common feature of being poorly distributed. Thus, the energy potential of each is restricted to certain specific sites. Although the exact location and extent of coal reserves is not known it appears that the distribution of ultimately recoverable coal reserves is about as follows: (8)

	Coal
United States	25.3
Soviet Union (including Eastern Europe)	49.6
China	14.2
Western Europe	4.1
Australia	2.6
Africa	1.7
India	0.05
Other America	1.4
Other Asia	0.05

Thus, apart from China and India, the developing countries do not appear to be well endowed with coal.

Major hydroelectric sites are fairly widely distributed and their exploitation promises to make a significant contribution to energy supplies for urban industrial centres. However, the energy they produce can only be economically transported a limited distance. Moreoever, the large initial costs of generation and transmission together with potentially serious health and environmental problems associated with damming large streams will inhibit exploitation of some sites. Geothermal energy sites offer another significant source of energy for selected developing countries once certain technical and environmental problems are resolved. It is unlikely to be a major source.

In summary, the sources of energy mentioned above, all of which tend to be centralized (except oil which can also be used as the basis for decentralized energy) will be useful in greater or lesser degree depending upon local circumstances. I do not believe they will be adequate to meet the needs of the developing countries especially the needs of the poor majority living in rural areas. If that is true, what are the prospects for meeting village energy needs for such tasks as pumping, lighting, grinding and (above all) cooking through harnessing locally available renewable sources? To answer this question we turn now to a consideration of solar energy technology.

IV. Solar Energy Technology

The current energy of the sun comes to earth in one of four major systems. First, the power of falling water is made renewable through the action of the sun in raising the water from sea level back up to the hills and mountains. Second, the wind is caused by the differing intensities of solar energy falling on different parts of the earth. Third, the photosynthetic character of green plants enables them to store solar energy in their edible tissues which is the basis of all life on earth. Finally, the direct energy of the sun's rays may be converted to heat or directly into electricity.

There is now an array of proven technologies, some of which are commercially available to convert solar energy into useable energy. We will identify five of them here.

1. Mini-hydroelectric generators

China today is reported to have about 60,000 such units averaging between 35 and 50 kw in capacity and ranging to less than 3 kw. Even the U.S., which at one time depended primarily on small mechanical and electric hydropower especially for New England industries, is reconsidering the potential of tapping its own small rivers and streams for electric power. A recent study by the U.S. Army Corps of Engineers estimated that new generating equipment at existing abandoned dam sites alone could contributed 54,000 mw to U.S. generating capacity (9). The U.S. Federal Power Commission maintains that partially developing only 10% of the U.S. 50,000 small dams would contribute power equivalent to using 180 million barrels of oil per year (or the same as reducing our daily oil imports of 7.5 - 8.5 mbd by ½ mbd) (10).

2. Wind

Wind has served as a source of power for over two millenia, ranging from the earliest windmachines used for pumping and grinding in the Persian empires to the windpumpers and aerogenerators which helped make the Great Plains of the U.S. habitable and productive for stock raising and farming well into the 1930s. In the U.S. alone over 6 million windmachines have been used within the past 100 years. (11) There are still reported to be 100,000 - 150,000 windmachines (mostly windpumpers) in use in the U.S. today (12). Perhaps as many as a quarter of a million standing but broken windmachines in the U.S. are in suitable condition to be easily repaired and operational again (13). In addition, the U.S. is experiencing a rebirth of interest in windmachines, especially aerogenerators, with sales up at least five-fold since 1974. (14) Both government and private groups in the U.S. and other industrialized countries have begun more seriously to explore the potentials of wider scale use of aerogenerators, ranging in size from less than 1 kw capacity to some well over 1 mw.

At a less complex level, the use of locally assembled sail wing windpumpers among the Geleb people of the Lake Rudolf/Omo River area of Ethiopia over the past few years demonstrates that there may well be good prospects for much wider use of the wind for mechanical uses in the rural areas of the developing countries (15).

3. Generating Methane Gas From Organic Wastes

The third proven technology is the generation of methane gas from organic wastes. Biogasification involves the fermentation of animal dung, human night soil, and organic farm and household debris and wastes in relatively air tight tanks, to produce methane gas. The gas may be used for farm, household, and cottage craft purposes. The process leaves a residue which is a liquid fertilizer in partially sterilized form. The technology is known and reliable, particularly where livestock are abundant, and has been used by thousands of farmers in Korea, Taiwan, China, and India and has been experimented with in Tanzania, Mali, and Ecuador, among other countries. There are problems with consistency of output during the cold session in high latitude or high altitude areas, and with costs of construction materials like steel, cement, tubing, gas appliance fixtures and adapted equipement.

The degree to which biogasification can be accepted and used will depend heavily on both the number of sedentary cattle or other animals from which dung can be collected and the willingness of villagers to collect and handle dung. For example, for most family size biogas units, dung from a minimum of five head of cattle is usually necessary. For village scale use, of course, there would have to be a substantial degree of cooperation involved both in collection of dung and in distribution of gas and fertilizer by-products. Biogasification has promise for those cultures with domesticated sedentary cattle, particularly if animals are penned or corralled (a practice which facilitates collection), and provided the people are accustomed to using dung (to build mud walls for homes, for example) or are otherwise willing to handle dung. It would require some careful investigation of cultural habits for each village or community to ascertain this potential.

4. Photovoltaic (pv), or Solar Cells

The fourth proven technology is photovoltaic (pv), or solar cells such as are used in space craft. They are usually made of wafer thin slices of silicon attached to wires and covered with or imbedded in glass. The action of the sun on these cells creates a continuous electric charge which is collected and carried off by the wires. Although the technology to make these cells is high, it takes virtually no technology to maintain them because there are no moving parts and the use of electricity requires only a moderately skilled operator.

The costs of the technology are currently too high for it to compete with diesel but rapidly declining pv costs plus expected rises in the costs of diesel fuel make it likely that pv will be competitive in the next five or ten years. This new technology may already be the best choice for certain uses in remote areas (e.g. water pumping or communications systems in villages where delivery of fuel and servicing a diesel engine present problems).

5. Simple Flat Plate Solar Collector

The fifth technology is the simple flat plate solar collector, an insulated box painted black on the inside, and covered with glass. The glass lets the sun's rays through where they convert to heat on contact with the black paint and the glass traps the heat from escaping. That heat can be used to dry fish, grain or tobacco, distill water, heat water and run a pump among other things. The technology for most uses does not require great skill either to construct from local materials or to maintain and operate.

V. Solar Energy Costs

Despite the numerous experiences with solar energy hardware, there are no systematic data on actual cost performance of solar hardware compared with (say) diesel or an extension of the electric grid. In August of 1977, however, the U.S. National Academy of Sciences sent a team of experts to Tanzania to sit down with the Tanzanian National Scientific Research Council and experts from the Government and the University to consider the matter of solar energy for the villages of Tanzania. These experts spent a week pouring over calculations of the costs of performing certain village tasks (a) with diesel engines, (b) with electricity from Tanzanian electric grid, and (c) with the five small scale solar technologies identified above. What they learned was encouraging for solar energy. Each of the five technologies is either now able to compete with diesel or will be able to do so within the next few years. Whereas the costs of diesel are about 2.3 shillings per kilowatt hour of electricity, the cost of mini hydro ranges from .26 to .97 shillings, of wind is 1.5 shillings, and of flat plate cooling is .98. Photovoltaic costs are now 11.6 shillings but if the U.S. Department of Energy target for price drops are chieved, the pv cell will cost .83 shillings in 1985. Currently the cost of energy from the electric grid in a village would be .88 shillings if it were available (16).

Moreover, there is a wide range of applications of such technologies to the performance of common village tasks as is shown in Table 3.

Table 3. Solar energy applicability matrix. Animals are included as a solar technology (based on photosynthesis). For sunny villages the use of animals would represent a modernizing step. It includes the use of dung for burning or fertilizing. Source: adapted from a presentation by J.R. Williams at the Tanzanian workshop. Symbols: ++, applicable; +, potential/applicable; -, not applicable.

Solar technology	Energy Use													
								Heating						
	Water pumping	Lighting	Cooling	Communications	Water desalting	Spinning	Sawing	Cooking	Space	Domestic water	Grinding	Drying	Transport	Fertilizer
Solar cells (flat plate)	+	+	+	++	-	+	-	-	-	-	+	-	-	-
Flat-plate collectors	+	-	+	-	++	-	-	+	++	++	-	++	-	-
Concentrating collectors	+	+	+	-	+	-	-	+	-	-	-	-	-	-
Solar, stirling	+	+	+	+	-	+	+	-	-	-	+	-	-	-
Solar, rankine	+	+	+	-	-	+	+	-	-	-	+	-	-	-
Wind (mechanised)	++	-	-	-	-	+	+	-	-	-	++	-	-	-
Wind generator	++	++	++	++	-	+	+	-	-	-	++	-	-	-
Water(mechanised)	++	-	-	-	-	++	++	-	-	-	++	-	-	-
Hydroelectric	++	++	++	++	-	++	++	-	-	-	++	-	-	-
Bioconversion wood/pyrolysis	-	+	-	-	-	-	-	++	++	++	-	++	-	-
Biogas	+	++	+	-	-	-	-	++	-	+	-	+	+	++
Draft animals	++	-	-	-	-	-	-	+	-	+	++	-	++	++

VI. Testing Solar Energy Potential

A. The Need for Village Level Tests

The Overseas Development Council was asked by AID to evaluate the prospects for solar energy for the villages of Africa. After completing our research we reported to AID that we could not answer the question whether solar technology holds great potential for village use for the reason that there exists no systematically recorded body of the experience of such technology at the village level. We recommended a period of actual village level testing and described the testing process needed. AID asked ODC and others to help set up some tests with the result that projects to test solar hardware in a sample villages have now been identified in seven African countries and a project identification effort will be undertaken in two or three more countries. If these projects are then well designed and skillfully executed, some answers to the questions of solar energy potential for Third World villages should be emerging within a few years. Without reliable evidence on this subject, Third World policy makers will be understandably reluctant to make a major commitment of resources to solar technology. Hence by default this technology will be by-passed and choices will be made among the proven conventional technologies—largely petroleum based.

B. The Nature of the Tests

These village tests should be designed to answer six questions:

1. How well does a given device perform technically within the physical conditions—including the all-important variable of settlement pattern of the village?

2. How do its costs compare with alternative energy technologies?

3. How does it fit the local culture?

4. What can be learned about the best techniques for introducing the technology into the villages?

5. How does it match existing or prospective village institutions that could own, operate and maintain it?

6. What is the effect of the increase in available energy upon such indicators of community well-being as literacy, infant mortality, income, migration and birth rates?

Each of these tests deserves further comment.

2. Physical Conditions. The selection of technology must match the physical circumstances of the village. A windmill requires a certain velocity of wind for a reliable period of time to function. Sandstorms may damage the glass on a photovoltaic cell, hydroelectric generators will not work if the stream is dry for several months during the year, humidity or salt spray may corrode metal parts, bio-

digesters are less effective at low temperatures and require the right mix of organic wastes and water, and a pyrolitic converter requires a ready supply of woody material to make charcoal, gas, and oil. Such a test should match various kinds of hardware with a range of physical conditions and measure and record technical performance, maintenance problems, safety record, breakdowns and the like.

2. Costs. Initial capital costs are easiest to measure. Other costs include maintenance, repair, and the costs of operating personnel. Solar equipment tends to have relatively high costs for purchase and installation but in many instances it costs very little for maintenance and operation over the remainder of its life. It is therefore important to know as soon as possible the approximate life of the project in order to compare it with diesel which costs less to install but a great deal more to operate.

3. Local Cultural Factors. Some devices may be less than acceptable to local residents than others because they offend local beliefs. For example, the design of a device may be reminiscent of an evil omen. Some devices may stir up family problems. For example, men may resent it if the first device introduced is one that only helps women. Since the men may be dominant in the locality this may kill the prospect of a successful experience with the device. The device may require the handling of cow dung which in some societies may be unacceptable.

4. How Does It Fit Village Institutions? Some technologies can be operated by an individual family. This might be true, for example, of a bio-digester in a culture where families own several cattle each, pen them up at night, and are willing to handle dung. A solar cooker that cooks by concentrating the sun's rays on a cooking pot could also be operated by an individual family in those cases where cooking is done in a pot, where there is no objection to cooking out of doors when the sun is high overhead. Other technologies are not amenable to management by single families. Thus a technology that produces electricity calls for some kind of village public utility. In some villages there is a tradition of carrying on activities on a village-wide basis. In others there may be no such tradition and hence it may be necessary either to avoid such a technology, or have it operated by a unit established from outside the village, or experiment with forming untried forms of village organization. Some technological applications might lend themselves readily to private enterprises. Thus, for example, a photovoltaic cell-driven grinder might be operated by a village entrepreneur who would sell the service of grinding corn or millet to people in the village. Similarly a pyrolitic converter to make charcoal out of fibrous waste, (e.g., wood, sawdust, coconut husks or peanut shells) might in some cultures be best managed by a small industrialist.

The range of applications is great and the cultural-institutional variations within and among villages are almost limitless. In order to give the technology the best chance of performing well, at low cost, and being well maintained, a great deal of thought needs to be given to the best institutional arrangement within the village for "owning" and operating the device. A great deal of field research has been done in many cultures and individual villages by sociologists and anthropologists. Techniques need to be found to draw upon this knowledge during the period when the project is being designed. The village test should make provision for observing and recording the performance of various kinds of village institutions in utilizing various kinds of hardware.

5. Introducing The Technology. Although there is much evidence that several technologies work, there is also a disquieting record of failures at the village level in many developing countries. Anyone who has travelled in developing countries extensively has come across the skeletons of windmills or the remains of abandoned bio-digesters. Although the reasons for these failures are not well documented, they probably include the normal quota of bad design and bad management by the project directors. One may also generalize that a leading cause of failure had to do with the technique for transferring the technology from the lab to the village. Outside experts came to the village with a pre-selected piece of hardware to do a pre-selected task (e.g., a windmill to pump). They erected the device, operated it for a time, tried to enlist the interest of certain villagers and then left. Shortly after their departure the device fell into disuse. Perhaps its parts were canabalized for other purposes. The failure may not have been technical or even economic. Rather it may have been a failure of the technique of transfer to enlist the enthusiasm of local persons or institutions so that they would incorporate the new device into the economy and the cultural practices of the village. The device was brought in by aliens and it remained alien. It never became part of the village.

No doubt the technique for introducing a project into a village will affect importantly the success of the project. My hypothesis is that involving innovative villagers in the very early stages of a project will increase the enthusiasm and involvement they have over the life of the project. It will increase the likelihood that the project will be incorporated into the life of the village, and the villagers maintain and operate the new device well and get the most out of it. Moreoever, involving villagers will improve the design of the project because villagers may have the most reliable opinions on (1) what task to select for energizing (e.g., pumping, grinding or cooking), (2) what primary energy source to use (e.g., sunshine, organic waste, animal power, or wind), (3) what device to use (e.g. wind pumper, wind generator, solar pumps, or solar cell), and (4) what village institutional arrangements to make for the operation of the device.

On the other hand, involving villagers in project planning has some drawbacks. It may be time consuming and hence unattractive to impatient Americans (or other foreign) aid officials or to host country operators. It calls for skills not always possessed by energy technologists. In many countries the normal method of dealing with villagers is to impose change from above. This normal technique, of course, requires the governmental office that imposes the change to supply a corps of people to operate and maintain the new technology. It is a much greater budgetary burden than if villagers could be motivated to take over maintenance, operation and simple repairs.

It is for each government to consider these advantages and disadvantages and decide whether to impose technology from above or to attempt to involve villagers in designing and implementing the changes. The fifth purpose of a well-designed test would be to furnish such governments objective data on the advantages and disadvantages of each technology transfer technique. Hence the test should attempt to determine whether involving villagers in the early stages of the project enhances the prospects for success.

6. Impact on Community Well-Being. Finally, the tests should be able to tell policy makers of developing nations something about the impact of new energy sources on the life of the villagers (or urban slum dwellers) and therefore ultimately upon the nation.

What is the impact of energy on agricultural production? Is a substantial portion of the labour released from other tasks devoted to raising additional crops or livestock? Does employment occur as a result? Are small industry or handicrafts stimulated by the coming of energy to the village? Does the provision of lights for reading improve the pace or quality of education? What effect is there with respect to health services or the incidence of disease (for example, from clean drinking water)? What effect is there on the role of women? Is there an increase, a decrease, or no change in the number of babies born each year? The AID-financed Evaluation Study of the MISAMIS Oriental Rural Electric Service Cooperative in the Philippines, concluded that, "The sharp decline in the crude birth rates (in the wake of electrification) is one of the most interesting phenomena uncovered by the study". Is there a change in infant mortality? What changes, if any, take place in the pattern of migration? Does energy set up a demand for imported items that drain limited foreign exchange? These and other evidences of the impact of energy on village life should be measured and analyzed in order to better understand the importance of village energy, to anticipate problems and opportunities it may create and to differentiate among the effects of different uses of energy (lighting, clean water, cooking fuel, for example, contrasted with irrigation) and different forms (electricity versus gas, charcoal or mechanical energy).

NOTES AND REFERENCES

1. Orally obtained from Brookhaven staff. To be included in a forthcoming study.

2. Reddy, A.K.N. and Prasad, K.K., "Technological Alternatives and the Indian Energy Crisis" in The Economic and Political Weekly, Special Number, August, 1977, pp.1465 to 1502.

3. Makhijani, Arjun, Energy Policy for the Rural Third World, International Institute for Environment and Development, London, September, 1976, p.21.

4. Adapted from Pimentel et. al., "Energy and Land Constraints in Food Protein Production", Science, November 21, 1975.

5. Levy, Marion J., "Modernization and the Structures of Societies A Setting for International Affairs". Vol. 1. Princeton, New Jersey, Princeton University Press, 1966. Pages 10, 11, 12, 35. We disagree with Professor Levy's exclusion of draft animals from the definition of modernization. While an economy based on animal power can scarcely be regarded as modern, it is certain more developed than an economy that relies on human muscle, as many still do.,

For a more recent statement on the subject, see MacPherson, George and Jackson, Dudley, "Village Technology for Rural Development", in International Labour Review, Vol. III, No.2, February 1975, I.L.O., Geneva, p. 99. These authorities "define 'technology' to mean a method of operating on the environment for man's benefit—usually seen in terms of sources of energy".

6. "Energy Needs, Uses and Resources in the Food Systems of Developing Countries", December 23, 1977. Prepared by David Pimentel with the assistance of workshop participants, College of Agriculture and Life Sciences, Cornell University, draft.

7. MacPherson, George and Jackson, Dudley, "Village Technology for Rural Development", in International Labour Review, Vol. III, No.2, February 1975, I.L.O., Geneva p.99.

8. W. Peters and H.D. Schilling, "An Appraisal of World Coal Resources and Their Future Availability" in World Energy Conference, Conservation Commission, World Energy Resources, 1985-2020, (New York: IPC Science and Technology Press, 1978), pp. 64-71. Percentages are based on "geological resources" estimates submitted most recently to the World Energy Conference. "Geological resources" are defined by the authors as "within an order of magnitude that can be regarded as realistic for those resources that may some day be of economic interest (sic) for the population of the world". The authors suggest that this may be a better frame of reference than current technology and economics since these are both going through a period of rapid change and are in part a reflection of a lack of exploration and development particularly in the Third World.

9. Lilienthal, David E. "Lost Megawatts Flow Over Nations's Myriad Spillways", in Smithsonian Magazine, September 1977, p.83.

10. Ibid.

11. Metz, William D., "Wind Energy: Large and Small Systems Competing". Science, September 2, 1977, pp. 971.

12. Hayes, Denis, Rays of Hope, 1977.

13. "Spreading Windpower Gospel", Washington Post, July 30 1977 (estimate of Professor M.I. Rashussen of New Mexico State University.

14. Ibid.

15. Fraenkel, Peter, "Food from Windmills", ITDG, London, 1975.

16. Brown, Normal L. and Howe, James W., "Solar Energy for Village Development" in Science, February 3, 1978.

INDIGENOUS AND INTRODUCED COMMON FIREWOOD AND CHARCOAL PLANTS OF KENYA

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SUMMARY

The pros and cons of using firewood and charcoal in Kenya are discussed. Afforestation is recommended and the introduction of quick growing trees emphasized.

INTRODUCTION

The most ubiquitous use of indigenous plants by man in a developing country like Kenya is in providing fuel for cooking. Majority of Kenyans live in the rural areas where cost of living is cheapest and wher e modern technology is least used. It is in the rural areas where people continue to use more of the natural products as sources of food, shelter, energy and so on. With an increase in population, there is always a parallel increase in demand for more energy, which eventually places more stress on the natural energy resources, the plants. Kenya is one of those African countries without any natural coal resources. Her peoples therefore, depend primarily on the easy availability of wood fuel for most of their domestic needs. Until a few years ago, even small industries as well as things like locomotive engines in the country were run on energy generated from wood. It is true that the energy used in most urban areas of the country now are from modern sources like electricity, gas or oil. But the fact still remains that majority of the people in the rural areas and even some in the urban areas continue using firewood or charcoal as their main source of energy. Plants as the main source of our energy nonetheless, have their limitation. Scarcity of fuel plants is being experienced all over the country. Most parts of Kenya are semiarid and in such areas where the rainfall is fairly low, the regeneration of plants is also slow. It is in these semiarid parts of the country where the impact on vegetation through human and animal use is more noticeable than in the humid parts. This is obvious because once the existing vegetation is cleared for land use which includes firewood and charcoal, there is always little rain to support the next generation of plants.

FIREWOOD

For a long time Kenyans in the rural areas have always considered firewood as one of the free gifts of nature in the same line as air and water. Collection of firewood, an occupation mainly done by women, is usually carried on an *ad hoc* basis whereever it occurs. This has been the common practice in the past when large areas of unoccupied forests and bushes were set aside for communal grazing and firewood collection. But even in pastoral and normadic areas where people used to wander from place to place, the trend is drastically changing. The idea of individual land ownership is now being realized all over the country. But despite all these, the fact still remains that a medium size family in the rural area uses between 1.5 to 2.3 cu m. of firewood a month when available. As the population increases, more land is turned into crop land and grazing land, while less unoccupied bushland and forests for collecting firewood become available. Firewood is sometimes obtained to a limited extent from bush growth in resting shambas and grazing lands. But apart from firewood, there are several other family needs for wood products such as building poles, tool handles, or production of charcoal as a source of income. It is a known fact that land is becoming very scarce in the rural areas, and each family may own quite a limited piece for all their needs. The government programme of land adjudication is being implemented in most rural areas.

The material used as firewood depends entirely on the type of plants growing in the surrounding. They vary from small shrubs to large trees, the latter being the better in quality and quantity. The variable climatic conditions in Kenya, however, control the distribution of good firewood yielding plants. There are a few parts of the country with ample annual rainfall to support both farm crops as well as trees for firewood. Vast areas of the country are covered with much more hardy and drought tolerant "thorn trees" of the genus Acacia. The acacias are widespread in the rural areas and make excellent firewood and charcoal. There are about forty species of Acacia in Kenya, all with good hard wood quality necessary for firewood. Another major source of firewood in the rural areas is from Combretum species. This group of plants are also very widely distributed in the country, forming the bulk of what are generally referred to as the savannas. As opposed to the "thorn trees", combretums are thornless and are easy to collect as firewood. They have good quality wood for both firewood and charcoal. Their close associates are Terminalia species which also have good wood. A large portion of the semiarid areas (mainly in the East, North-East as well as parts of Coast and Rift Valley Provinces) are covered with Commiphora species. Commiphoras have somewhat poor quality (soft) wood but are used as firewood wherever available. Euphorbias are also a common feature in the arid and semiarid areas. Though they are used as firewood, the quality is not so good. The other genera commonly sought for as firewood whenever available are Albizia, Bridelia, Allophyllus, Grewia, Lannea, Markhamia, Teclea, Rhus Piliostigma, Annona, Phyllanthus, Harrisonia, Strychos, Entada and Vitex. These exclude the giant forest species.

The rural population continues to grow while the natural vegetation continues to be exploited for human use including firewood. The indigenous species providing firewood are known to be slow growing, and the replacement of the already harvested trees requires many years. A family with a limited area of land would, therefore, need fast growing trees which can give them quick and economical returns. In many areas in the rural, firewood is no longer a free gift of nature as has been regarded in the past. It is actually becoming an asset to own trees in one's farm. Every family in the rural area must be encouraged to plant some trees in their land. Hill slopes, river banks or swamps should normally be set aside for tree planting.

Such unsuitable land for cultivation can best be utilized that way, and trees planted on them will also reduce soil erosion. The government through the Department of Forestry should make it a policy of distributing fast growing tree seedlings to all farmers. Through personal observations and experience, the "gum trees" (Eucalyptus species) are fast growing, good wood yielding and can grow in varied climatic conditions. They have a quick and somewhat perpetual way of regeneration through "Coppice" which are new outgrowths from previously harvested clumps. In fact the regeneration is so prolific and ensures a continuous wood yield with least labour costs for maintaining the plantation once established. There are over twenty species of Eucalyptus which have been tried in various parts of the country. The Eucalypts or gum trees had been introduced into the country from their native land Australia. They grow very fast even from seeds. Since the country's requirements for fuel cannot be met from the few forest areas, plantations of eucalypts should be encouraged on a wide scale. Eucalyptus saligna (Sidney Blue Gum) is a fast growing, abundant wood yielding, and easily adopted species which is highly recommended. The main advantage of a eucalypt over an indigenous species is that it takes about ten years for the eucalypt to yield the same quantity of wood as from a thirty year old indigenous species growing in the same land. Eucalypts when planted on 3 m. by 3 m. lines, can attain an average height of 30 m., with a stem thickness of 1 m. d.b.h. after only ten years. Swamps can best be utilized by planting Eucalyptus robusta (Swamp Gum) which normally does well in such areas. This would ensure a source of income to a farmer who owns such unsuitable land for crop production. One would argue that swamps can be used for rice production, but this is not always true since such land requires expensive machinery and labour to be changed suitable for crop production. A farmer who is allocated a swampy land in the rural area can therefore, produce timber products which can be sold as firewood, building poles, timber or processed into charcoal. Eucalyptus paniculata (Grey Ironbark) usually does well in areas with marginal annual rainfall,such as Eastern Province. One interesting factor with this species is that it has good quality hard wood compared with the other two species already mentioned. The other species which does well in dry areas and are suitable for firewood are E. camaldulensis, E. citriodora, E. cladocalyx and E. sideroxylon.

Other trees suitable for dry areas includes Cassia siamea, a medium sized exotic tree. This leguminous exotic tree is drought resistant, tolerant of many types of soil, completely resistant to termites even when young, and coppices readily. It grows rapidly from seed, usually reaching 1.5-2 m. in the first year, and can be ready for good firewood between 10 to 15 years. The yields from an average quality plantation averages 59.3 - 74 cu. m. per acre of firewood.

CHARCOAL

Charcoal is another source of energy widely used in Kenya and also exported. It is primarily produced in the rural areas where the wood is available but sold to urban dwellers who use it abundantly. For the rural Kenyans with enough forests and woodlands around them, charcoal is a major source of income whenever they can produce it. This is particularly so in the semiarid areas where cash crops may not grow well due to low rainfall. Most areas in the Eastern and North-Eastern Provinces as well as Masailand are semiarid, and I have observed that apart from livestock, tobacco, cotton and a few horticultural crops, charcoal is usually among the leading five to ten exports of the districts. Production of charcoal is carried in all provinces in the rural areas and exported not only to urban areas but also overseas and to Somalia. Coast Province which has both semiarid and wet forests and woodlands has been a leading exporter of charcoal to Arabian countries in the Middle East. During the late 1960s and early 1970s the rate of charcoal export to Kuwait alone was in the region of 35,000 tons per year. The question which each of us will immediately ask is "why do Arab countries with plenty of oil import Kenyan charcoal?" This question is answered as follows : Firstly charcoal prices once imported are comparatively cheaper than oil as a source of fuel in those countries. Secondly I had been told that certain industrial work is better done by charcoal energy than by electric or oil energy.

Material for charcoal production:

Contrary to firewood material, charcoal production is primarily from large woody plants especially the trees. Naturally, trees are major components of forests and woodlands. Kenya is however, very deficient in forests, and of her total land surface area forests cover only 17,700 sq. km. which is about 3% of the total area. This is very low compared to what most countries in the world have as an average of 10%. It has been estimated that during mid 1970s, about 300,000 cu. m. of both charcoal and firewood were used from our forests per annum.

The best charcoal both in quality and quantity, is obtained from the hardwood indigenous forest trees. But such trees are normally also used for production of building timber. In the forests, lumbering takes priority of the best tall straight trees while the poor quality trees are left for charcoal burning. Acacia species are widespread in the country and are a major source of charcoal. They normally do not form straight boles suitable for timber or building poles. They have profusely branched crowns, and hard wood which makes the best quality charcoal. Some of the most widely used tree species for charcoal production in the country are Acacia abyssinica, A. gerardii, A. hockii (White thorn), A. kirkii, A. lahai (Red thorn), A. macrothysa, A. nilotica, A. polyacantha, A. senegal (Sudan Gum Arabic), A. seyal (White Galled Acacia), A. sieberana, A. tortilis and A. xanthophloea (Fever Tree or Naivasha Thorn). Next to the acacias are the Combretum species as a source of charcoal production. The most widely used are Combretum collinum subsp. binderanum, C. molle, C. schumannii and C. zeyheri. Both Terminalia brownii and T. kilimandscharica are relatives of combretums and are also widely used. Good quality charcoal is also obtained from Faurea saligna, Croton megalocarpus, Millettia leucantha, Bridelia micrantha and Vitex doniana. This list excludes the large forest species predominantly found in the wet forests and those parts of the country with ample annual rainfall.

Methods of preparing charcoal :

There are several methods which have been used and are still being used in the preparation of charcoal by different charcoal producers in the country. The various methods have both advantages and disadvantages which may be or may not be known to the local charcoal burners. One factor which I have noticed is that some types of structures built for burning the charcoal produce less amount of charcoal per given amount of wood than the other kind of structures. This is one important point in which the modern expert can advise the local farmer how best to utilize wood from his land. I shall now comment on some familiar methods of preparing charcoal in the country.

1. Charcoal Stack

This is one of the oldest methods of preparing charcoal in the country. It is normally built on a level site, and with the apex or front end from which the fire is lit, slightly raised in order to help the fire creep to the end. Its floor is marked out with pegs in an almost triangular shape, with the dimensions varying from 5 m. to 9 m. long and from 0.5 m. to 3.5 m. wide. Such a stack once built resembles roughly a half longitudinal segment of a cone lying on the larger of its flat surface, see Fig. 1.

In building a stack, stout poles are laid covering the ground, each pole laid with its thinner end towards the apex or the front end. Poles which are generally straight, are laid close to each other. The ground layer is then covered with straight dry sticks to help the fire to creep through, and such pieces of sticks are normally packed in between the poles. The dry sticks should not exceed 50% of the stack, and the sticks are frequently arranged more at the apex and sparser towards the rear end. The reason for packing more dry twigs at the apex is to enable the fire to spread quickly. The top layer of poles may be greener than the lower layers, and can be packed even with fresh green sticks. It is a common practice that a built up stack should contain no large ventilations.

The materials used for building a stack are normally half-dry poles varying from 4 cm. to 20 cm. in diameter, and are cut into pieces from 1 m. to 2.5 m. long. All material is then trimmed clean to allow close packing, and the thick bark removed to help the material dry out quickly. Thinner branches are trimmed and cut up into sizes varying from 0.8 m. to 1.5 m. and used as packing and firing material, and it is recommended they are used when fully dry.

Covering the stack:

Once the stack is built, it is covered with a layer of green grass 3-5 cm. thick. Brick-shaped sods are then cut and built over the stack from the ground level upwards, with the grass layer side facing inwards. The final cover of the stack is a medium layer (10-25 cm. thick) of damp soil which is spread all over to pack it down firmly and to fill up any possible interstices. There are square apertures of 20 cm. by 20 cm. left at the bottom of the apex end which are used to admit the fire when being started, and there are 4-5 small more evenly spaced square vents (12 cm. by 12 cm each) at the top of the rear (posterior) end.

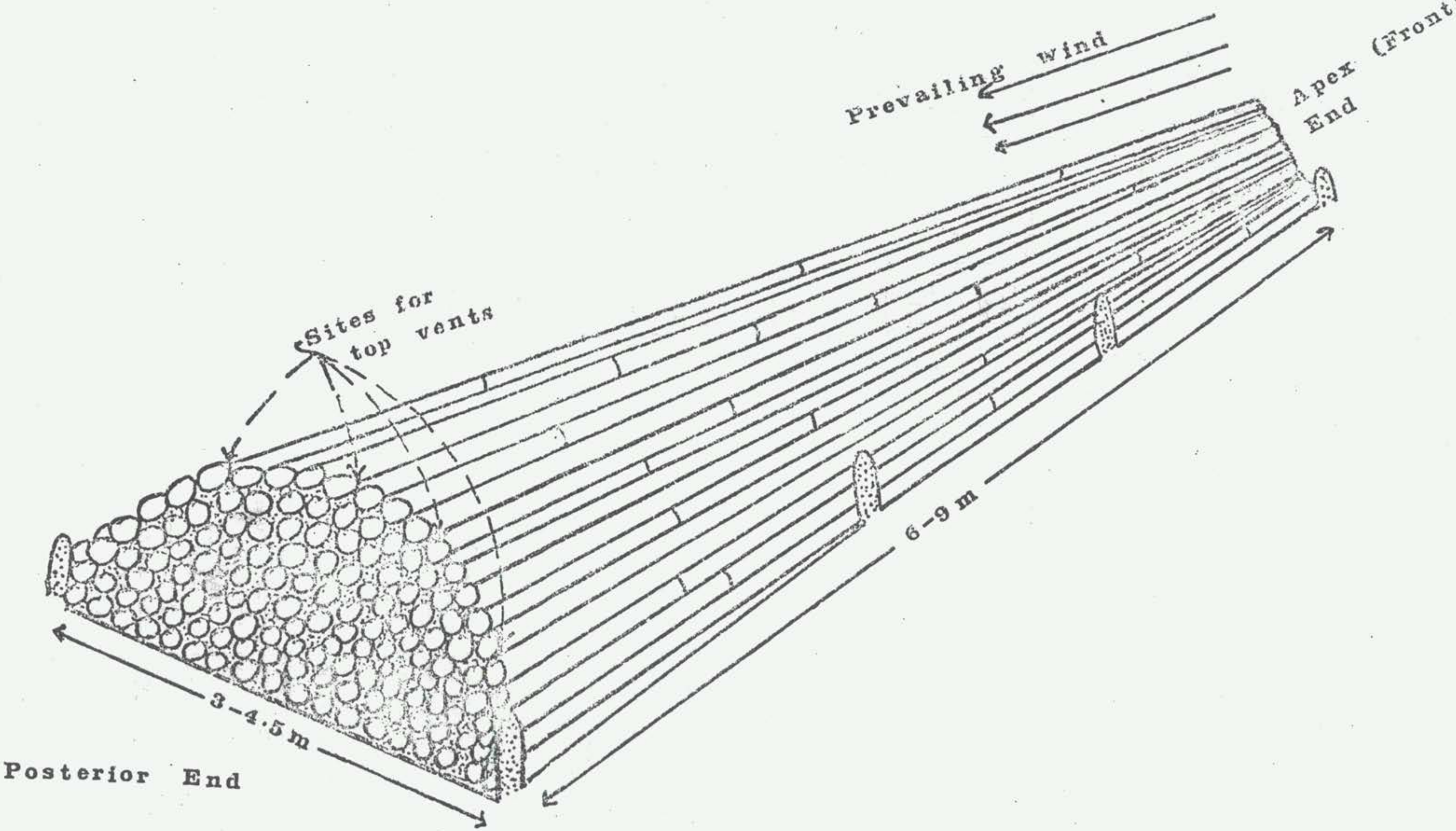

Fig. 1 CHARCOAL STACK

Firing the stack:

After covering the stack, some sods and damp soil are placed nearby to fill up any self-created vent holes which normally appear in the stack once burning begins. The fire is now lit through the main aperture at the bottom of the apex (front) end. This main aperture is gradually reduced in size as the fire continues, and eventually blocked completely after about 2-3 hours and after the fire has covered approximately a sixth of the stack. Depending on the size of the stack, but in general the fire usually takes up to two days to reach the rear end of the stack once lit. During the normal burning for the first 12 hours the vent holes at the top rear end of the stack are left open. Three to four new vents (about 10 cm square) are made on the floor level at the rear end, and these enable the fire to continue burning after all the other vents have been closed. The main reason for closing the vents in sequence as the fire continues to burn is because if left open longer than necessary the wood lying next to them will burn out completely instead of forming into charcoal. It is important the stack is continually watched as it burns, and to close immediately any cracks releasing smoke and flame. In the normal burning procedure, the smoke will cease after 3 - 6 days, and once this is noticed the stack is allowed to cool for another 2 - 4 days before being opened. After these periods, the stack is then opened, again beginning from the apex end. Since charcoal is still hot at this stage, it is spread out to cool by using a shovel or such like tool. Well burnt charcoal is later separated from half-burnt wood, the former being packed in sacks and transported to consumers while the latter is placed into the next stack to be burned.

2. Pit and Brick Kilns

Another common structure for burning charcoal used by the local people is a Pit kiln. The procedure for building it is fairly similar to the "Stack", except here a pit is dug in which pieces of wood are placed and only the top to be covered as opposed to the building of the sides of the stack. A better kiln so far in burning charcoal which can produce more is that permanently built of bricks, and is called Brick kiln. Although brick kilns are the least known or least used by the local charcoal producers, they are the best in quality as well as quantity. Experiments have shown a lower output of charcoal from a pit kiln (45 kg. of charcoal from 6 cu. m. of wood) as compared to 90-135 kg. from 6 cu. m. of wood obtained from a brick kiln.

It is interesting to note that although the current local charcoal burners have reverted more to pit kilns than charcoal stacks, the latter was somewhat superior to the former since it is closer to the brick kiln type though more cumbersome to operate. I would, therefore, strongly recommend a change to the permanently built brick kilns to be used in areas where charcoal production is a major source of income, and if found expensive they should be built through co-operative societies. The ordinary pit kilns also have the disadvantage of the charcoal being contaminated by earth since the walls of the pit frequently shred. An improved "Metal-lined pit kiln" would be a better alternative to ordinary pit kiln. Such a kiln can be constructed by using old bodies of lorries to line the walls of the pit.

3. The CUSAB Charcoal Kiln :

All the preceding described kilns for processing charcoal are not capable of making use of the small wood material for production of charcoal. A more interesting kiln capable of carbonizing small shrubs, bushes or twigs was designed in 1971 by E.C.S. Little, FAO expert working in Nairobi. The Cusab Kiln as it is called, is capable of making charcoal from the abundant shrubs and bushes or any woody material cleared from the farms or rangelands. It is constructed from a sheet-metal which is welded into a portable unit weighing about 1.5 tons. This kiln is handy because it can be easily transported from place to place, depending on the area where bush is being cleared or the availability of the raw material. Some of them are made such that they can be towed, or they can be carried on tracks. It operates on a 24 hours cycle, and has a daily output of 20-30 bags (c. 700-1000 km.) of both charcoal lumps and charcoal fines. It has a total volume of 8 cu. m.

With a few modifications and improvements on the Cusab kiln type, a new kiln has now been designed by a company in Nairobi known as Burns and Blane (Kenya) Ltd. This new type of kiln is reported to produce up to 800 kg. of both charcoal and charcoal fines from an input of about 2.5 tons of woody material daily. Working on a 24 hours cycle, it is estimated to operate between 200 and 250 working days per year.

Apart from the usual firewood, charcoal is the cheapest source of fuel in the country. Charcoal is also the main fuel used in Kenya by low and medium income groups in both urban and rural areas. With the use of this modern kiln, we can even produce enough to export without creating precarious conditions to the vegetation and soil. There is however, one major problem with trying to use small woody material, and that is the production of abundant charcoal particles and dust instead of the reasonable size charcoal. This would require another type of machine, a briquetting machine to convert the dust into charcoal. Briquetting machine would actually be suitable at a place where there is large accumulation of wood by-products such as those from a paper factory, in order to be economically feasible. I should suggest the use of reasonable material, namely shrubs of good size to produce good charcoal. As I had mentioned before, most parts of the Republic is shrubland, therefore obtaining woody material is not a problem. The Cusab kiln can very well use some of the common shrubs like Leleshwa (Tarchonanthus comphoratus) common in Rift Valley, the Black-galled acacia (Acacia drepanolobium) a major shrub in black cotton soils of the savanna vegetation, Combretum and Acacia species which are the dominant shrubs in most parts of the country. A modern Cusab charcoal kiln would cost between Shs.4,000/- and Shs.6,000/-. Since most farmers in the rural areas may not afford such a price, I would recommend formation of charcoal co-operative unions in those areas with vast unused or less used shrublands. Alternatively small companies can operate in particular rural areas, may be at location or division level. The Cusab kiln has an advantage of higher yields than the traditional pit kiln, therefore a co-operative union or company will definitely make some profits. I may just point out that the major problem with ordinary kilns is the difficulty of controlling the amount of air-during carbonization. This is the main cause for low production of charcoal obtained from temporary kilns used by local charcoal burners.

Since the Cusab kiln produces high quality charcoal from undesirable woody material, and with the least effects on useful vegetation, I strongly appeal to our government through the ministries concerned to encourage its use.

CONCLUSIONS

Considering the raw material used in traditional fuel, we find that we are dealing with a fairly delicate issue which normally involves pros and cons. Many conservationists in the country have always spoken against the use of trees as a source of fuel. As far as the use of firewood goes, this depends primarily on the accessibility rather than the quality of the plants being used. Nonetheless, there are particular plants especially trees which are normally preferred as good firewood. There is therefore, a high demand of trees in the country since charcoal production also depends primarily on them. Charcoal produced in Kenya is not only consumed locally, but a large quantity of it produced particularly at the Coast Province has been exported to Arabian countries in the Middle East. In recent years, some Provincial and District administrations have banned charcoal export and/or charcoal production. Export ban can be implemented and supported by many Kenyans, but production ban cannot be supported fully since charcoal is a major source of energy in the country. With the price of electricity doubled this year, 1979, the use of charcoal in the urban areas has even increased.

It is true that indiscriminate felling of tree for both firewood and charcoal production usually leads to reduction of natural cover, increases soil erosion, and the final result is desertification. This process is noticeable in semiarid areas of the country where both charcoal production and livestock keeping are the major occuptions. Once the trees and shrubs of such an area are cut and followed by heavy livestock grazing and browsing, the land eventually becomes bare and soil erosion commences. But since charcoal is a major source of fuel in Kenya, provides employment and income for a number of farmers in rural areas, its raw material production should be increased. It is recommended that afforestation should be increased, quick growing trees such as Eucalypts and Cypress should be planted, and fast regenerating trees such as Combretum collinum and Eucalypts should also be planted.

REFERENCES

Kokwaro, J.O., 1974, Advantages and disadvantages of charcoal burning in Kenya, United Nations Environmental Programme (UNEP - IDEP) workshop on environment and rural development in East Africa, Nairobi.

Kokwaro, J.O., in Odingo, R.S., 1977, The Vegetation: Kamburu-Gitaru ecological survey, Department of Geography, University of Nairobi, Nairobi.

Kokwaro, J.O., 1978, Ecological facets of unique vegetation types of tropical Africa, with special reference to East Africa, Universität Bayreuth, Bayreuth, West Germany.

GLOBAL ENERGY RESEARCH: IMPLICATIONS FOR SWEDEN AND KENYA

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SUMMARY

Annual global energy R and D expenditure presently amounts to some 10 Billion US$, very unevenly distributed among the countries. Only a very minor fraction is directly concerned with the needs of developing countries even though a somewhat larger part of R and D results can be successfully transferred. Those countries now face a double-sided energy transition, both away from oil in the modern sector, and away from traditional fuels in the rural sector. An analysis of the structure of the Swedish Energy R and D programme is used as a background for an outline of some crucial issues facing the build up of a comprehensive Kenyan Energy R and D programme. Two aspects of energy R and D programmes in developing countries are stressed: the need for integration between studies within different areas and the need for strengthening the informed energy constituency in order to improve the possibilities to evaluate energy matters from a national standpoint. On the other hand, immediate action is required in a number of areas, independent of the establishment of a concerted energy R and D programme.

INTRODUCTION

Before 1973, no country had established a coordinated energy research programme. Today, certainly all industrialized and a growing number of developing countries have established high priority energy R and D programmes, covering all conceivable aspects of the energy systems. Total costs of global energy R and D today, amounts to some 10 Billion dollars (depending on the way of calculation), about one-third of military R and D. Especially conspicuous has been the growth in energy conservation and renewable energy studies, supplementing earlier research which was very strongly concentrated on nuclear fission and fusion energy supply technologies. The global reason for this change in perspective is of course the change of outlook for the oil market, but many other factors have also been working although different in different nations.

For some industrialized countries (IC's), what has happened gradually with the nuclear aspirations and planning lead to an interest for alternatives to both nuclear and oil, preferably environmentally benign and domestic ones. Others also became aware of the potential for exports of energy equipment open to the leaders in the technological race. One of the main tragets were the developing countries (the LDC's). Many IC's have had to face the common problem of caring for energy industries created for the high growth future anticipated in the sixties, and found difficult to support in the more gloomy futures of today. At the same time, environmental concern increased, and expectations about renewable energy became higher as R and D results started to pile up.

For many LDC's, in addition to the oildriven troubles mainly affecting their modern/urban sectors, energy-related problems in the rural sectors also show signs of becoming increasingly severe. The firewood crisis is potentially the most catastrophic of them all. Over and above, the discussions in the LDC's about the possible necessity for a reformulation of present developing strategies focusing on the problems of the rural poor, have contributed to a new interest in the energy's role in development. Also here, environmental concern and solar expectations have become more pronounced.

All these well-known issues form part of the common basis for the reformulation of energy R and D policies, that has taken place in most nations during the last five years.

GLOBAL ENERGY BACKGROUND

It is generally agreed that at the present time, developing countries are only using up to about ten per cent of the world's annual supply of commercial energy (principally fossil-fuels, nuclear-energy and hydro-power) the remaining 90 per cent going to the industrialized countries. Several authoritative projections (e.g. World Energy Commission 1977; International Institute of Applied Analysis 1978) anticipate that the developing world's share will tend to double, approximating to close on 20 per cent by the year 2000. The energy use of the developed countries is also expected to grow during the coming two decades, maybe by as much as one third or even a half in spite of conservation measures.

In order to get a clearer picture of what these percentages mean in terms of the actual additional energy-resources needed and hence in terms of their implications for environment and development, it may be more useful to look at the actual amounts of extra energy that will be needed annually rather than the percentages themselves. Table 1 shows a growth in commercial energy requirement in the industrialized countries from 90 units to 120 assuming an increase of one third, i.e. an additional requirement of 30 units annually by the year 2000. All figures are very approximate and are intended only to illustrate the trends. (The increased requirement would of course be 45 units if a 50 per cent growth is assumed).

Table 1

		Annual amounts of energy required (arbitrary units)		
		1978	2000	Extra
Developed Countries	Commercial	90	120	30
	Non-Commercial	1	1	1
DC	Total	90	120	30
Developing Countries	Commercial	10	25	15
	Non-Commercial	10	25	15
LDC	Total	20	50	30

Note: This assumes growth of one third

In the developing countries however, the increase is from 10 up to 25 units - an additional need of 15 units. This more dramatic rate of increase in LDC's is being driven by population growth and societal changes in the Third World. Population is expected to double in many developing countries during the next two decades and the pressure this creates on land availability tends to force migratory and pastoral peoples to settle down and adopt agriculture, or stimulates urbanization. These social changes all cause an increase in per capita consumption of energy dictated by the new life-styles adopted.

The use of non-commercial energy (principally wood fuel, charcoal, dung), is virtually negligible in the industrialized world whereas in developing countries it counts for at least as much as the commercial energy use and in many Third World countries, anything up to three times as much again.

The growth of additional requirement in this former energy sector is expected to be just as dramatic as the commercial energy growth in the Third World (i.e. 10 up to 25 units). This means that the extra annual energy burden to be borne by both developed and developing countries will be roughly similar by 2000.

If this is the case, the implications of this for the Third World are very serious. Developing countries already spend a disproportionately high percentage of their GDP on oil imports (frequently 10-20 per cent, compared with 3-5 per cent in industrialized countries). The problem of finding currency to pay for the very large additional amounts of commercial energy will be overwhelming particularly in the present oil-price situation in a hardening global market which is already having the effect of forcing some Third World energy users back onto charcoal and wood. In the non-commercial sector, the existing rate of depletion of forest and woodland, especially in the drier regions of the world, casts grave doubts on how sustainable a fuel-wood supply will be in the future.

GLOBAL ENERGY R AND D

It is certainly no surprise that global energy research is concentrated to certain countries in the same way as other research. It is either no surprise that the bulk of expenditure concerns technologically very advanced and large-scale methods, such as various nuclear, coal-gasification or fusion schemes. Even looking at the more than 800 M$ that the world is estimated to spend annually on solar energies, a very minute fraction is concerned with projects designed to meet needs outside the IC's. Table 2 gives a rough overview of the public spendings in some key countries. Table 3 shows the relation between private and public spending in different time-perspectives for global energy R and D. Table 4 shows data on energy R and D in the IEA countries.

The data in Table 3 can of course only be indicative, since very few good surveys of global energy R and D are available, and collection of data is very difficult, especially in developing countries. Also, dollar expenditures do not tell the full truth about either the size, importance or success of a programme. Most costs concern salaries, which differ markedly between countries. Further, some methods for improved energy supply and use, which may become of great importance, will require very moderate or almost none research, such as efficient firewood or solar stoves. Others may require enormous amounts of research dollars, such as breeders. Both may then ultimately be met with considerable problems when it comes to social implementation.

However, some general observations can be made from available data. Energy R and D is totally dominated by the industrialized nations, and in particular by a handful of OECD/IEA countries. At best the developing countries may account for two per cent of the total energy R and D expenditure, similar to R and D conditions in general. In term of manpower, the LDC share may rise to some ten per cent. Also, most of the R and D is directed towards solving short-term supply problems in the IC's, i.e. fossil, nuclear and conservation, or highly sophisticated future technologies, i.e. fusion, breeders or solar "power towers".

However, a considerably larger fraction of the global energy R and D results than the few per cents mentioned above will of course be of interest to the LDC's, and will be made available on commercial or other terms.

Table 2 : Public funds for Energy R and D in six countries (Million US$). (1977)

R and D area	USA		Japan		FRG		UK		Canada		Total		Sweden	
	$ x 10^6	%	$ x 10^6	%	$ x 10^6	%	$ x 10^6	%	$ x 10^6	%	$ x 10^6	%	$ x 10^6	%
Oil and Gas	48,8	1,7	0,5	0,1	5,5	0,9	22,3	9,3	5,3	4,4	82,4	1,9	0,4	0,7
Coal	395,0	14,1	13,1	2,5	72,0	12,0	2,9	1,2	6,3	5,2	489,3	11,4	2,4	4,1
Biomass etc.	4,5	0,2	0,3	0,1	-	-	0,4	0,2	0,4	0,3	5,6	0,1	1,4	2,4
Conv. nuclear	358,6	12,8	178,6	33,7	270,7	45,0	85,1	35,5	83,3	68,8	976,3	22,7	12,9	21,9
Breeders	594,4	21,2	89,0	16,8	158,1	26,3	92,3	38,5	-	-	933,8	21,8	-	-
Fusion	328,5	11,7	30,3	5,7	35,1	5,8	11,5	4,8	1,7	1,4	407,1	9,5	3,8	6,5
Geothermal	53,4	1,9	11,1	2,1	0,9	0,2	0,3	0,1	0,3	0,2	66,0	1,5	0,7	1,2
Solar	146,8	5,2	5,7	1,1	11,0	1,8	1,9	0,8	4,9	4,0	170,3	4,0	2,5	4,2
Wind	15,0	0,5	-	-	2,5	0,4	0,2	0,1	0,9	0,7	18,6	0,4	1,8	3,1
Ocean thermal	9,5	0,3	0,6	0,1	-	-	1,7	0,7	-	-	11,8	0,3	0,3	0,5
Other sources	-	-	2,1	0,4	0,6	0,1	5,8	2,4	1,9	1,6	10,4	0,2	1,4	2,4
Conservation	63,5	2,3	41,9	7,9	22,0	3,7	11,8	4,9	11,0	9,1	150,2	3,5	23,1	39,2
Supporting prgms	782,0	27,9	156,9	29,6	22,9	3,8	3,4	1,4	5,0	4,1	970,2	22,6	8,2	13,9
Total	2800,0	100,0	530,1	100,0	601,3	100,0	239,6	100,0	121,0	100,0	4292,0	100,0	58,9	100,0

Table 3: <u>Global energy R and D Distribution</u> (1977)

Shaded areas show proportion of public funding
White areas show proportion of private funding

Surfaces of circles are proportional to money expenditure.

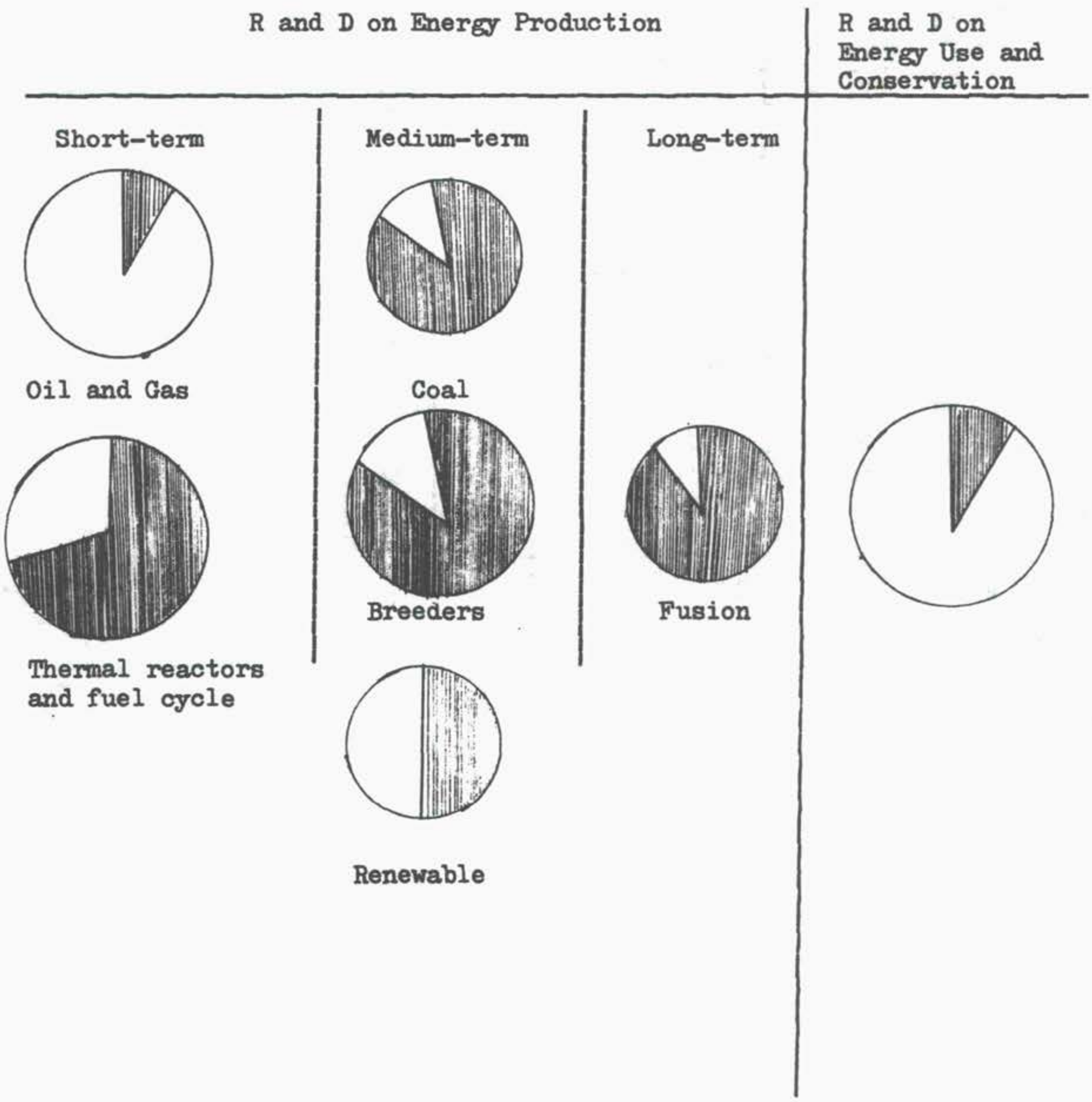

Table 4 : Energy R and D data for IEA countries (1977)

Country	Energy R, D and D expenditure ($US millions equiv)[1]	Total Primary Energy Consump. (Mtoe)[2]	Gross Domestic Product ($US billion equiv) (Est)[3]	Population (Millions) (Est)[4]	Energy R, D and D Expenditure per capita ($US)	GDP per capita ($US thousands)	TPE per capita (toe)
Austria[6]	11.2	25.5	48.38	7.505	1.5	6.45	3.4
Belgium[5]	87.1	44.5	77.87	9.838	8.9	7.92	4.52
Canada	121.0	207.0	191.47	23.467	5.2	8.16	8.82
Denmark[5]	16.9	21.0	42.44	5.088	3.3	8.34	4.13
Germany[5]	601.2	260.0	519.29	61.223	9.8	8.48	4.25
Greece	n.a.	14.0	25.74	9.284	-	2.77	1.51
Ireland[5]	1.5	7.6	9.00	3.197	0.5	2.82	2.38
Italy[5 8]	264.2	138.0	194.67	56.493	4.7	3.45	2.44
Japan	529.9	357.0	685.96	114.008	4.6	6.02	3.13
Luxembourg	-	4.3	n.a.	0.354	-	n.a.	12.15
Netherlands[5]	109.7	62.5	105.76	13.894	7.9	7.61	4.50
New Zealand	3.6	11.0	14.50	3.141	1.1	4.62	3.50
Norway	22.0	22.0	36.14	4.047	5.4	8.93	5.44
Spain	42.8	69.0	116.80	36.675	1.2	3.18	1.88
Sweden	58.6	49.0	77.99	8.244	7.1	9.46	5.94
Switzerland	11.0	23.5	61.28	6.289	1.7	9.74	3.74
Turkey	13.7	31.0	39.75	42.065	0.3	0.94	0.74
United Kingdom[5 7]	234.6	213.0	241.23	55.945	4.2	4.31	3.81
United States	2800.0	1800.0	1865.51	216.624	12.9	8.61	8.31

1. Exchange rate: June 30th, 1977
2. Source: IEA, Quarterly Statistics
3. Source: OECD, Main Economic Indicators (Sec. Estimates).
4. Source: OECD, Monthly Economic Indicators (Sec. Estimates).
5. The expenditures of the EC Member countries do not include their contributions to the EC programmes
6. Austria indicates there is substantial energy research done by Universities, funding for which is not identifiable and therefore not included in these amounts.
7. With respect to nationalised industries, the United Kingdom figures include only the expenditures on energy R, D and D financed by government funds. Other expenditures by nationalised industries on energy R, D and D were £42 million in 19‾4 rising to an estimated £83 million in 1977, of which details are given in footnote 6 of Table 5.
8. Italian figures include personnel and infrastructure costs.

First, their modern sectors will for a long time continue to require imports of advanced technology, and will remain adjusted to use it. Second, as mentioned above, IC industries see a large export market emerging in the LDC rural sectors as well. This market may become of increased significance due to the increased interest in the LDC energy sectors now shown by e.g. OECD and many national and international aid agencies. Lead times and other obstacles for the establishment of indigenous LDC energy equipment industries seem sufficiently large to prevent significant changes in this situation for the next decade or two. Third, in some IC's, special R and D efforts are now being started or recommended aiming specifically at LDC needs and markets.

ENERGY R AND D IN DEVELOPING COUNTRIES

Even the tiny proportion of global energy R and D taking place in the Third World is however quite many-faceted and the profile of expenditures vary greatly between countries. Many countries have already established special energy R and D programmes, others are in the process of doing so. A number of cooperative programmes are also emerging. In most countries at least some studies of relevance for the energy situation is taking place. Such studies may include forestry, erosion, housing, migration patterns etc. Energy is as pervasive to living in developing as in industrialized countries,only the scale and complexity of tools vary. Table 5 gives an overview of non-conventional energy R and D in the LDC's.

Faced with the problem of building up an energy R and D programme in a LDC, one thus seems to be led to focus on renewable energy sources, especially for the rural sector. The main reason seems to be that many high-technology, large-scale systems may sometimes be completely transferable between IC's and the modern sector of developing countries. The short-term problem here, as seen from the LDC point of view, seems less one of research but more one of qualified man power, capital formation and trade balance. Research on rural renewable energies, although not necessarily unsophisticated, tends to stay cheap and solutions have to be worked out and adapted to local environmental and societal conditions. In most cases this requires only relatively simple technology.

Table 5: Summary of R and D activities in non-conventional sources of energy in developing countries

Country	Solar heating	Solar cooling of buildings	Crop drying	Water pumping	Solar electricity: thermal	Solar electricity: photovoltaic	Wind energy	Biological energy	Energy from the sea	Geothermal energy
Argentina	X		X			X	X			
Barbados			X				X			
Bolivia			X			X	X			
Brazil	X		X			X				
Chad		X			X		X			
Chile	X				X					X
China	X		X							
Costa Rica	X		X				X			
Cuba		X					X			
Ecuador	X									
Egypt	X			X	X		X			
El Salvador										X
Guatemala	X		X							
India	X			X	X	X	X			
Iran	X		X		X	X				
Iraq	X									
Israel	X	X		X	X	X		X		
Jamaica	X		X							
Jordan	X									
Kuwait	X				X	X				
Malawi	X		X							
Malaysia		X	X		X	X		X		
Mali		X			X					
Mauritius		X								
Niger			X	X	X					
Nigeria			X							
Oman					X		X			
Pakistan	X	X	X			X		X		
Papua New Guinea			X	X						
Peru	X		X							
Philippines	X		X				X			X
Qatar					X					
Saudi Arabia	X		X	X	X	X				
Senegal	X				X					
Singapore					X			X		
Sri Lanka	X		X	X			X			
Sudan			X							
Thailand			X	X			X			
No.of countries engaged	22	7	21	8	15	10	12	4	-	3
% of No. of countries listed	58	18	55	21	39	26	32	11	-	8

Source: United Nations, "Research in non-conventional sources of energy: Report of the Secretary-General" (E/C.8/56), January 1978, Annex (Summary of responses sent by the Member States of the United Nations to the Secretary-General's note verbal concerning their current programmes on research and development in non-conventional sources of energy).

Table 6: Swedish Energy R and D

Subdivisions of the Main Programme, the responsible agencies and the budget for energy R and D.

Programmes, subprogrammes	Responsible agency[f]	Funds for previous 3-year period 75/78, Million SKr	Budget for 3-year 3-year period 78/79-80/81 Million SKr	Funds for fiscal year 78/79 Million Skr
Energy use in Industrial Processes, etc.	STU	43.5	86	22
General studies				1
Wood pulp, paper				8
Iron, steel		35		6
Other industrial processes				3
Agriculture, horticulture				1
Recycling and recovery		8.5		3
Energy use for Transportation		26	32	9.5
Transportation systems	TFD	6	8	2.5
Energy use in vehicles	STU	20	24[a]	7[a]
Energy use for Buildings	BFR[b]	68	155	46
Energy conservation			44	14
Heat pumps			21	6
Solar heating systems incl. energy storage, etc.		54	35	10
Planning, control mechanisms, statistics			11	3
Consumer requirements			10	2
Planning and evaluation of experimental building activities		14[g]	34	11
Energy Supply	NE	215.8	393	133
Domestic fuel sources 1			100	30
Coal			15	5
Synthetic fuels 2			22	7
Light water reactors			14[c]	14
Hot water heating 3			22	7
Wind energy			105	35
Advanced energy technology 4			50	15
Fusion			65	20
General energy system studies	DFE	6.2	15	4.5
Fundamental research	-[d]	16.8	30	9
For later distribution[e]		-	96	7.5
Planning and coordination	DFE	6	12	3.5
International cooperation and other efforts related to the Main Programme		21.5	23	7
Total budget		403.8	842	242

1 biomass, peat etc.
2 methanol etc.
3 geothermal, waste, district heating
4 solar power, hydrogen, wave energy, advanced nuclear

(1 US $ = 4.5 Skr)

[a] Part of which for investigations and development work concerning the use of synthetic propellants.

[b] STU is responsible for industrial development work within the subprogrammes Energy conservation, heat pumps and Solar heating systems incl. energy storage. Other R and D projects, the overall planning of the programme as well as the planning and evaluation of experimental building activities are the responsibility of BFR.

[c] Only for the fiscal year 78/79.

[d] For allocation to STU, the Swedish Natural Science Research Council and Studsvik Energiteknik AB.

[e] For use, among other purposes, for certain large pilot and experimental plants.

[f] STU = National Swedish Board for Technical Development
TFD = Transport Research Delegation
BFR = Swedish Council for Building Research
NE = National Swedish Board for Energy Source Development
DFE = Energy Research and Development Commission

[g] Only for the fiscal year 77/78.

In short, the dilemma that has to be addressed by LDC energy policy and thus R and D planners, is a doublefaced one of two simultaneous transitions. The solutions may however be at least partly counterproductive. In the same way as the IC's, the LDC modern sector will be forced to replace oil in the future. In the rural sector it is already now an urgent task to replace (or at least supplement) traditional fuels with other energy forms. However, presently available substitutes for many tasks seem to be oil products.* Added to this the heavily increased requirements of energy to support rural modernisation and urban migration will also have a tendency to increase oil demand. Thus one of the main tasks of the LDC energy R and D will be to develop and put into use domestic energy, substituting both imported oil and dwindling traditional fuels.

The availability of oil substitutes for the modern sector will however largely depend on energy policy and R and D in the IC's. Global availability and price of oil is also to a certain extent depending on the same factors. Substitution of traditional fuels (and the emerging oil market) in the rural and informal urban sectors will to a larger extent depend on policy measures and the success of R and D programmes in the LDC's themselves. Energy R and D programmes in the developing countries are then not only sharing the problems of IC's, but will have to face the additional, and maybe much more severe, task of improving a deteriorating rural energy situation. In spite of th e focus on rural problems and the need for locally adapted solutions, the energy research programmes now emerging in many LDC's seem unnecessarily isolated and repetitive. Few countries seem to embark on efforts that really utilize the possibilities of international cooperation extending the projects far outside the realm of building and testing standard technical devices. Two obvious exceptions are the Indian nuclear and the Brazilian "gasohol" programmes. Those programmes despite of using large-scale, high-technology, maintain very strong national profiles, establishing an international lead in their respective areas. There seems to be opportunities for similar initiatives by LDC's on many areas, either through specialization in national programmes or within the broader context of regional cooperative projects.

THE CASE OF SWEDEN'S ENERGY R AND D PROGRAMME

The Swedish energy research programme is presently organized in 3-year periods: the first began in 1975 and ended in 1978, and the next will end in 1981. The 1975-78 period, has, of course, not seen many concrete results, due to the long time required to build up such a

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*An analysis of the consequences of this apparent contradiction is conspicuously often absent in reviews of LDC energy policy options: On the one hand oils has to be replaced, on the other hand oil is still the cheapest and most versatile energy source available.

large and new programme. In fact, major results from the most important programmes are not expected until the mid-1980s. On the administrative side, a complete restructuring of the earlier organization took place, with a new Energy Research and Development Commission as the overseeing coordinating body connected to the Ministry of Industry, where most of the energy questions belong. The Commission consists of 8 members, 5 of which represent political parties, one industry, one the scientific community and one is head of the secretariate. Actual research and administration is distributed among a number of old and new institutions. Most important of the new research bodies created was the Board for Energy Production Research, which was given the responsibility for all technical research on energy production - from fusion to biomass. Research on energy conservation in industry, in transport and in buildings was given to the existing organizations which already deal with non-energy research in those fields. The Energy R and D Commission itself kept the responsibility for the non-technical energy studies, the so-called General Energy System Studies programme, including ecological, economical and societal studies. A programme on energy-related fundamental research was also started, administrated by the research councils. The concentration on energy conservation and nonconventional energy in the first 3-year research programme reflected the energy bill of the former government in 1975, which called for a gradual decline in the increase of energy use and even zero-growth after 1990. The total sum of money devoted to the energy research programme in the first period was 404 Million crowns ($90M). The present programme for the 1978-81 period is still more concentrated on the same issues, i.e. the four topics of energy conservation in industry, solar heating and seasonal storage, biomass and wind. The total expenditure for 1978-81 amounts to 842 M crowns ($ 187 Million) for th e whole programme (see Table 6), a doubling since the former period. No dramatic increases are foreseen in the total budget for the next period. It is especially interesting to note that solar energy in various forms got almost one quarter of the total, and conservation over one third. In fact, Sweden spends more per capita on solar energy research than any other country. Besides wind, biomass and solar space heating, research on other forms of renewable (solar) energy in the "Main Programme" is funded at comparatively much lower levels. None of them either offers an energy potential similar to the main alternatives mentioned above. Regarding solar thermal power, photochemistry, photovoltaics wave and salt gradient energy etc., only small projects (mainly literature studies) and participation in international projects take place. The ambition is to maintain a certain level of domestic competence in order to be able to assess and evaluate the usefulness of global R and D results from a Swedish point of view. In some cases it is also possible to take advantage of certain available "niches" of Swedish expertise. Limited projects on hydrogen energy, fuel cells, methanol use, geothermal energy are also funded, together with a programme on General Energy Systems Studies concerning e.g. economic, institutional and environmental studies of solar and other energy at large.

This apportioning on conservation and solar reflects the fact that Sweden depends on foreign oil imports for about 70 percent of its energy supply. Naturally, most parties involved in the energy question consider this to be the most important problem affecting Sweden's energy supply today. In light of this situation the Energy R and D Commission proposal for the energy programme was based on the following general objectives:

> "Future energy supply is to be secured in such a way that the long-term total costs to society are kept as low as possible, that the negative effects on health and environment are within acceptable limits, and that other social objectives are not jeopardized. This, then requires changes of today's energy system:
>
> 1. A more efficient utilization of energy - particularly in the use of oil.
> 2. Greater flexibility in production and utilization of fuels and other energy carriers.
> 3. Diversification of the energy supply, primarily by replacing oil with other energy sources.
> 4. Increased domestic supply of energy."

At present, there are two main paths for achieving these changes: improving efficiency in energy use and substitution of oil with other energy sources. The prospects for more efficient use of energy, by utilization of techniques available today, are comparatively good, even though energy in Sweden is used more efficiently than in most other countries. As for the supply of energy, only a few alternatives to oil are regarded as technically available now - coal, natural gas, nuclear energy and hydropower. Coal, natural gas and uranium have to be imported, and the possibilities of increasing the production of hydropower are limited for environmental reasons. Although Sweden has 80 percent of Europe's uranium reserves, these large shale deposits are not ye t commercially exploitable. And because of the long lead time required for mining operations to become productive, they will certainly not have any impact on the energy balance until about a decade from now. At this point a decision to go ahead with uranium mining is extremely uncertain due to the very intense nuclear debate. Also the future of Sweden's nuclear reactor program is by no means clear. It is a politically explosive issue due to the dispute about safety questions and conflicting opinions regarding the size of Sweden's future energy needs. A referendum is set for the spring of 1980 on the nuclear issue. Hence, the accepted picture of the future is that in the 1980s and 1990s there will be a serious risk of oil supply shortages coupled with increases in the relative price of oil. It is therefore seen as a necessity that Sweden prepare itself to 1) facilitate the introduction of already existing alternatives to oil, and 2) allow for a transfer to new energy sources and employ new methods for more efficient use of energy.

The energy production sector (the "energy producers"), manufacturers of energy-using equipment and others are already doing development work which will gradually change the energy system. However, there is a risk that this work is not extensive and quick enough to permit us to bring about the changes which a secure energy supply necessitates. The object of the governmental energy R and D programme is to promote and accelerate the development and thus assist in creating new means for energy conservation and supply. The programme therefore concentrates on

- producing knowledge required to assess the conditions for introducing new technologies or new systems of energy supply; important aspects are economic consequences, health and environmental effects and the possible rate of introduction

- supporting the development of technologies required to change the energy system in accordance with the objectives of the energy policy

- to some extent to contribute to the spread of new technologies and new systems for improved energy supply

- increasing knowledge about the relationship between the energy system and other societal functions as well as its international aspects

The energy R and D programme is intended to give financial support to research, development and invention. But the programme does not directly support the commercial introduction of new systems. This responsibility rests primarily with producers and users of energy. The R and D programme can, therefore, normally support development only up to a point when energy users or producers themselves can start to use the technology or develop it further, or when introduction is stimulated by other means. Government grants to investments in prototypes or demonstration plants within industry and commerce are examples of such stimulants. For energy use in buildings similar possibilities exist to obtain support for experimental building activities. In some instances, however, a technology has to be tried out on a large scale before its further development or implementation is decided upon. It may thus be necessary to build large pilot plants. In such case support from the energy R and D programme will be relevant mainly when there is no established organization which can naturally assume responsibility for testing the technology in question.(The item "for later distribution" in Table 4 is designed for this purpose among others).

As mentioned above, health and environmental questions are also parts of the energy problem. Research in these matters therefore is an important part of the energy R and D efforts to utilize new energy sources, new energy conservation techniques, etc. The programme does not normally, however, finance projects covering health and environmental effects of energy technologies already in use. Those areas are usually covered by the Board for Environmental Protection.

The selection of projects within the energy R and D programme is done in the light of the energy policy objective described above, i.e. to create new means of energy supply and to promote energy conservation. Many factors are taken into account when considering the support of a project in practice. In most cases assessment is based on the following factors:

- What importance could the method have for the national energy supply as a whole?

- What will the cost be - per energy unit and power unit - for supply distribution, storage or conservation of energy by this method?

- What are the health and environmental effects - and are they acceptable?

- To what extent is state support needed for development and introduction of the method in Sweden? (When Swedish enterprises themselves undertake the development work or when other countries carry out work from which Sweden may benefit, state support may be less warranted).

These grounds for assessment are mostly used for development work directed towards practical applications. Besides such work the energy R and D programme also covers fundamental research as well as general studies and investigations for which other grounds for assessment may sometimes be used. During the first three-year period 1975/78 the energy R and D programme has had a relatively broad character. The aim has been to obtain better knowledge of the conditions for utilizing various energy sources and energy conservation techniques. In many areas the efforts have been of a planning or pilot study character. During the three-year period 1978/81 the projects will be more concentrated to particular fields, but a fairly large number of lines of development remain to be examined and evaluated. Even with the larger budget for the energy R and D programme, its future support will probably be more concentrated on fewer and larger projects. Sweden is a member of the IEA, and participates in almost all of its cooperative research programmes. Swedish R and D results, status reports, planning documents etc. are published regularly, many of them in English, and are available from the Energy R and D Commission or from the various research agencies.

SWEDISH ENERGY R AND D IN CONTEXT

Seen from a Swedish point of view the first phase of the "Main Programme" is fairly comprehensive and adjusted to the need for policy re-orientation. The mix of overview studies and forced efforts in selected areas may seem reasonable. The underlying philosophy, at least for the supply programmes looks something like: "try everything once". Time-phasing of the main areas is made in such a way as to yield major results in the mid 1980s. This is also the time when a series of large energy decisions will have to be taken in the light of R and D results and the outlook of the international energy market. On the other hand, it has been argued that the efforts on alternatives to fossil and nuclear is still too small to really achieve the goal of keeping options open while waiting for the major energy decisions set for the mid 1980s. The momentum of the present development regarding coal, nuclear options etc. may cause e.g. the solar option to be foreclosed before any decisions about future directions are really taken. It is interesting to note, in this context, that Sweden's solar energy prospects are unusually good considering its northern situation and high energy use per capita. Already now some 20% of Sweden's energy comes from solar (wastes in paper and pulp industries, hydro), and theoretical studies indicate the potential possibility of total energy self-sufficiency for Sweden using only solar options (solar heating, large-scale energy forests, wind, hydro etc.)

Seen from an LDC point of view, the usefulness of the results of the Swedish and other similar R and D efforts are naturally much more limited. A preliminary outline of some Swedish experiences which could possibly become of value for the LDC energy scene is shown in the following :

Modern/urban sector:	Industrial conservation (paper and pulp; reprocessing)
	Space heating (heat storage)
	Biomass (pyrolysis, silviculture)
Rural sector:	Biomass (plantations, agro-forestry, housing)
General:	Planning and systems analysis (industrial energy planning; regional planning; technical systems analysis and evaluation; research planning)
	Environmental studies etc. (reclamation, emissions, health, safety)

In addition to the sectors outlined above a number of possible future interlinkages in the energy field outside the R and D area have to be added such as construction of power stations (hydro, nuclear, fossil), regular scientific exchange, possible future development aid in the energy area (probably focussing on the rural sector) etc. Other energy-related inter-linkages may result from development aid and commercial cooperation regarding housing, water supply, geophysical exploration etc.

Seen in a global context, the contact surfaces between LDC and IC energy sectors are of course much larger. This is true especially in the commercial energy sector, where the LDC's to a very large and probably growing extent are dependent on the IC's for the supply of technology, machines and maintenance. In addition pressures are high from the IC industries for new markets in the energy sector. The Third World share of total exports is already significantly higher for this sector than for other items, where the LDC share of exports is usually around 10%.

SOME ASPECTS OF KENYAN ENERGY R AND D

The future Kenyan energy R and D has been outlined in a paper by Githinji at the National Energy Symposium in 1978. The objectives of this policy are very similar to those formulated for Sweden. The Kenyan energy policy encompasses the following:

1. Making the country less dependent on imported oil and coal, which are going to place an increasingly heavy financial burden on the nation.

2. Development of technologically sound and economically feasible devices for the utilization of the non-conventional energy resources which are widely available in the country, particularly in the rural areas.

3. As a result of the above two to diversify the nation's energy base beyond the present three resources : Oil, hydro and wood/charcoal.

4. Intensification of exploration for energy resources (oil, coal and uranium) in the country.

5. Training of Kenyans in research, design, development, and production in the energy field.

The type of energy research projects most often discussed for LDC programmes, concern work on technologies of various energy supply methods. However, in the Swedish example, studies on various supply technologies amount to not more than some 50% of the total expenditure. Conservation, environmental, societal and systems studies certainly have a place in any energy programme, as have energy forecasts of supply and demand.

Conservation and increased efficiency is often the cheapest, but almost always the quickest and most easily accessible domestic "energy source". In addition, it can usually be "mined" using already available manpower. Environmental, societal and integrated systems studies are mainly tools for establishing the direction and limits for technical research, and may prove to be of decisive importance for a successful injection of improved technology into any type of society.

The usefulness of forecasts is obvious for achieving a good energy planning, provided forecasts are done openly and with great care, including both demand and supply studies. The recent (and rather monumental) mistakes in energy forecasts in the IC's, may serve as warning examples, one of their costs being the development of energy industries which sometimes seem to be grossly mismatched to existing market conditions.

The organisational structure chosen in Sweden, involving a semi-political coordinating governmental body, and actual research split up between a number of specialized agencies, may not be appropriate to other countries without the manpower resources and infrastructure existing in an advanced IC. On the other hand, an interdisciplinary and interagency governmental body (e.g. within the NCST) would seem necessary as a coordinator and focal point in order to integrate matters of energy policy, energy R and D etc. into general national technological and developmental goals.

The proposed multidisciplinary Energy Research Centre may be another way of using scarce resources in a country like Kenya. Such a centre especially if coupled to a practical field service organisation, to industry and energy planning authorities, could provide another useful focal point.

A main function of such a centre, besides providing actual R and D results, should also be to act as the center-point for strengthening the informed energy constituency needed for evaluation of projects, strategies and for systems analysis in the energy sector. The importance of such a group is especially obvious when facing a future with increased need for international cooperation for managing global energy problems and for independent national assessment of foreign technologies.

An integrated, multidisciplinary, approach to the energy R and D problems is thus necessary, adjusted to the objectives of a comprehensive national energy policy and strongly coupled to national development objectives. In case of Kenya, this appears to mean a two-front war on the issues raised by the modern and rural transitions. The central problem, at least in the short term perspective, appears mainly to be one of taking initiatives, selecting and funding some of the most urgent projects and push them ahead within the limits of existing resources (in addition to already ongoing activities). As in the case of Sweden, time does not allow much delay.

A number of possible projects, mainly concerning the energy supply sector, are discussed in the paper by Prof. Githinji. I will not try to go into any detail about the status, availability and suitability of various energy sources, but clarification of the technical options available to Kenya is no doubt one of the most pressing needs for R and D. A large number of other urgent tasks will be given in other contributions to this Work-Shop.

In the medium-term, adoption of strategies for energy R and D becomes another central problem. For example, what is a proper balance between self-sufficiency and imports, or between long-term basic research and short-term "marketing" efforts? What criteria with regard to time-scales, energy potential, rural vs urban applicability etc could be established for support of projects? What amount of financial and manpower resources are or could be made available? Is there a need for a Kenyan initiative in the direction of establishing an LDC counterpart to the cooperative IEA R and D programmes? In the longer term, further build-up of national energy planning and evaluation capabilities may prove to be the best guarantee to secure a favourable energy development on the nation's own terms.

A few potential projects and areas of concern for the build-up of an integrated energy R and D programme are outlined in Table 7. The table is by no means complete but only meant as a framework for further discussions, which will provide guidelines for selection of worthwhile and feasible projects and for the organisational structure and resources needed for a successful effort.

Finally, let us return to the similarities between the general objectives of Swedish and Kenyan energy R and D. Of course, this is no coincidence, given that both countries are small and restricted to a large foreign dependence. Neither country has its own fossil fuels, both have considerable hydro resources and both face an uncomfortably large and tenacious oil dependence. Renewable energy does also seem to be playing a large future role in both countries. In spite of all other enormous and self-evident differences, it is, therefore, hoped that the Swedish experiences can be of some value for the energy development of Kenya.

Table 7 : Potential topics for R and D programmes of Kenya

POSSIBLE TASKS	EXAMPLES OF SUBJECT AREAS
Gather basic facts	- Rural/urban energy use - Domestic energy resources - Global energy outlook - Follow-up of global energy R and D
Planning/forecasting	- Rural transition strategies - Modern transition strategies - Formulation and discussion of national energy plans - Participation in international studies - Energy R and D coordination
Scientific Research Programmes	- Domestic energy source development - Conservation and efficiency studies - Participation in international or regional programmes - Environmental studies
Other	- Strengthening independent national evaluation capacity - Encourage the build up of local (village) competence in the energy field - Serve as a forum for education and independent discussions - Keep up international scientific contacts; invite scientists from IC's and LDC's - Take initiatives in building up an LDC energy R and D network - Provide expertise to serve as a counterpart in e.g. North-South dialogues

SELECTED REFERENCES

"Research, Development and Demonstration in the Energy Area - a Global Overview", Swedish Energy R and D Commission, Rpt No 12, 1978 (in Swedish)

"Energy R and D in Sweden 1978 - 81", Energy R and D Commission, Rpt No 13, 1979

"Directory of Research and development projects within the Swedish Governmental Programme for Energy R and D 1975/76 - 1977/78", Swedish Energy R and D Commission, Report no 20, 1979

"Sweden boosts alternative energy research", Kristoferson, L., Ambio VIII, 4, 1978

"Solar Energy Research in Sweden", Kristoferson, L., International Solar Energy Congress, ISES, Atlanta, 1979

"World Energy Resources 1985 - 2020", World Energy Conference, IPC Press, 1978

"Energy in a Finite World - a Global Systems Analysis", IIASA Draft, October 1978

"Coping with the Energy Crunch in Kenya", Papers from the first National Energy Symposium, Nairobi, NCST, 1978

"Solar - 2000", UNEP Report No 8, 1979

"Energy Supplies for Developing Countries : Issues in Transfer and Developing of Technology", UNCTD, Trade and Development Board, TD/B/C.6/31, October 1978

"Non-conventional Energy Sources - Potentialities for Africa", UNESCO; Regional Office for Science and Technology for Africa, Nairobi, November 1978

"Solar Energy in Developing Countries - an Overview and Buyers Guide", A. Eggers-Lura, European Helios Centre, Denmark, Pergamon Press, 1978

"Alternative Technologies and Third World Needs : A Case of Emerging technological Dependence", H.K. Hoffman, Science Policy Research Unit, University of Sussex, UK, October 1978

"Socioeconomic Effects of Rural Electrification", A. Hjort, Dept of Social Antropology, Stockholm University, 1974

"Problems in the Generation and Diffusion of Appropriate Technologies" A.K.N. Reddy, ASTRA, Indian Institute of Technology, Bangalore, 1977

"Sun: Mankinds Future Source of Energy", ISES Congress, 1978, New Delhi (The Extended Abstracts Vol. 1, contains i.e. a number of useful Reviews of National Solar Energy Research Plans)

"Potential International Solar Energy Markets", SRI International, Menlo Park, California, September 1978

"Technology for Solar Energy Utilization", UNIDO, Vienna, 1978

"Report on the Project Group Meeting on Alternative Energy Resources", Commonwealth Science Council, November 1977 (Rpt CSC(77)AER 1,2 and 3)

"Towards a National Energy Policy", Energy Development Board, Metro-Manila, The Philippines, 1977

"Solar Energy from France", Delegation for New Energies, Ministry of Industry and Research, Paris, 1978

"African Goals and Aspirations", Report of a Symposium held in Arusha, Tanzania 1978, published by SAREC, Stockholm 1978

"Energy in Developing Countries - Policy Recommendations for SIDA", Draft Report to the Board of SIDA, Stockholm 1979

"Science and Technology for Development", Swedish National Report to the Uncsted, Stockholm 1978

"Workshop on Energy Data in Developing Countries", IEA, Paris 1979

"Renewable Energy Sources for Developing Countries - an initial appraisal", prepared for the Ministry of Overseas Development, Energy Technology Support Unit, AERE, UK, September 1978

"Renewable Energy for Developing Countries: A Preliminary Assessment of the Potentials", Interim Report prepared for: Conservation and Renewable Energy Branch, Dept. of Energy, Mines and Resources, Canada, February 1979

"Workshop on Solar Energy for The Villages of Tanzania", Tanzania National Research Council, Dar es Salaam, 1978

"Energy for the Villages of Africa, Recommendations for African Governments and for outside donors", J.W. Howe and Staff of Overseas Development Council, Washington D.C., 1977

THE ENERGY LINK BETWEEN THE NORTH AND THE SOUTH - MORE QUESTIONS THAN ANSWERS

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SUMMARY

The developed countries (the North) and the less developed countries (the South) are linked in numerous ways. This paper raises a number of issues and questions about the nature of this link between the North and the South, such as :

- is it reasonable to assume that there is not enough oil available during the next two decades to fuel a high economic growth of both the North and the South and that thus either group has to plan to deliberately get out of oil?
- is it reasonable to expect that the coming 10-20 years will have substantially lower economic growth than the previous 20 years?
- if this is the case, is it reasonable to expect a combination of free trade patterns (or reinforcing of these patterns) or is it more reasonable to expect a growing tendency towards protectionism, bilateral agreements and regional, inwardlooking cooperation (the self reliant North)?
- is it reasonable to assume that oil is the single most important commercial fuel for the majority of the LDC's and that other commercial fuels (coal, gas) are an order of magnitude less important?
- is it reasonable to assume that the demand for oil in the LDC's will be more directed towards lighter grades also in the future?
- oil is more easily replaced in the North than in the South, where capital intensive technologies such as gas, electrification etc. are more easily introduced. Is it reasonable to assume that this will take place?
- what is a fair deal between governments and international industry in developing indigenous oil resources?

Answers are only rarely given, and the main theme for discussion should therefore be whether these questions are the right ones or whether there are other, more central ones, that have not been identified.

INTRODUCTION

The developed countries (the North) and the less developed (the South) are linked in numerous ways. There are a number of inherent dangers in trying to treat energy as a separate link in this relationship. While there is a case for studying energy in industrialized and thus specialized economies as a subject of its own it is not at all clear that the same type of separation is meaningful when studying less specialized economies. Nevertheless it is useful to use a working hypothesis that 1) the availability and cost of energy is a potential bottleneck for the development of Southern economies, and that 2) energy possibly also is a bottleneck for the economic health in Northern economies and that thus 3) global constraints on energy may affect both the North and the South.

The aim of this paper is to raise a number of issues and ask a series of questions about the nature of this energy link between the North and the South. Answers to questions raised are only rarely given, and the main theme for discussion should therefore be whether the right questions are being asked or whether there are others, more central ones, that have not been identified.

SOME GLOBAL ENERGY STUDIES

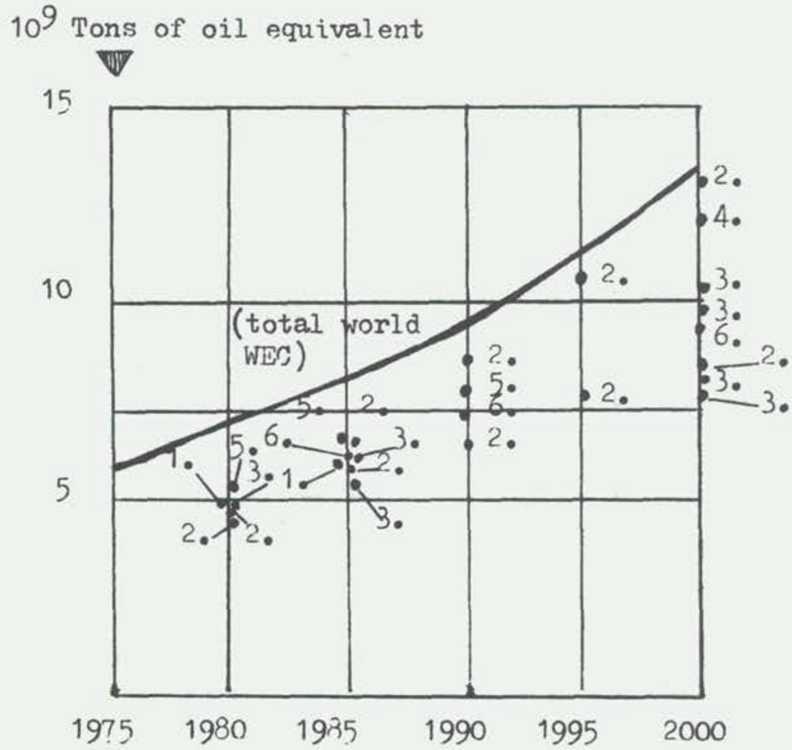
A number of studies have expressed concern over the future global availability of energy. WAES said the situation required "an unprecedented degree of international collaboration" as well as "the will to mobilize finance, labor, research and ingenuity with a common purpose never before attained in time of peace". The authors thought that failure to take appropriate action could create major political and social difficulties. Other studies in which the same conclusions have been reached have been published by OECD, WEC, IEA, CIA (1977), the Trilateral Commission, the Rockefeller Foundation etc. Many of these studies have predicted serious problems emerging in oil supply as early as the mid 80's, unless strong action is taken. Some later studies (Exxon, Petroleum Industry Research Foundation, RAND Corporation) have painted a somewhat more optimistic picture of the near-term (i.e. 80's and possibly early 90's) availability of oil. The optimism is caused mainly by reductions in demand, due partly to reduced economic growth and partly to increased conservation. Early 1978 the findings in Mexico have added further to the optimism, particularly in the US, but late 1978 the Iran crisis and the rapidly rising awareness of the inherent socio-political instability in many oil-producing countries have had an opposite effect. For the medium-term future (the rest of the century) mainly oil has been in focus. All studies agree that the projected supply of oil under certain circumstances may fall short of projected demand, with rapid price increase, political disturbances etc as possible mechanisms for closing a projected gap. The timing of this projected shortfall differs between different studies, as Table 1 shows. It should be noted that all studies use essentially the same methodology and the same database. Moreover, apart from WEC, and to some extent CIA, all studies refer to the world outside centrally planned economies!

Table 1. Projections of World Oil Shortage

Source	Estimated probable date when demand exceeds production capacity Date
CIA	By 1985
Department of Energy	1980-1985
U.S. Energy Information Agency	1980-1990
Brookhaven National Laboratories	1980-1990
International Energy Agency	1985-1990
Rockefeller Foundation	Late 1980's
WAES	1985-1995
World Energy Conference	About 1990
PIRINC	After 2000

On the long term (past the turn of the century) picture all studies essentially agree - the world economy has to replace oil by something else. It is, however, still too early to say which are right on the medium term issue – the previous more alarmed studies or the later somewhat more reassuring ones. The rather rapid oscillations between gloom and brightness in forecast of oil illustrate the lack of a common perspective. Many of the more optimistic studies have been based on physical or economical assessments of reserves and resources, while many of the more pessimistic studies derive their arguments from essentially the same database but interpreted in a more political and institutional framework. It should also be remembered that all these studies are "battle-cries" and "call for actions" and thus intended to be "self-denying". Therefore the somewhat more reassuring tone of the later studies could partly be seen as a result of some of the actions taken by governments, industries and households in response to the earlier more alarmed studies. A large part of the uncertainty stems from uncertainty in energy demand. Figure 1 shows some results (Grenon, 1978).

Forecasts of energy demand for WOCA



1. OECD
2. Shell
3. WAES
4. EDF (France)
5. Exxon
6. WEC (World Energy Conference)

As can be seen, the difference between the various forecasts for the year 2000 is in the same order of magnitude as the total use in 1975. One of the main reasons for the tendency in most recent years to lower demand forecasts is a growing pessimism about the future world economy. A prolonged recession would strain national economic policies and would possibly have important implications for (growing?) marginal groups in the North as well as for the LDC's. One of the most critical questions in the global energy situation is thus whether higher (or normal) economic growth inevitably will lead to oil supply problems. Another question is to what extent it is possible to decouple energy and economic growth in the developed world. Yet another critical question for the general climate of the North-South relations is the economic health of the North, especially if it is not possible to decouple the energy-GNP link in the North.

It should be stressed that the knowledge of the Energy-GNP link in developed countries is rather poor. The forecasts mentioned above all use rather crude models, based on historical correlations of income - and sometimes price elasticities of energy and overall GNP-projections. The role and possibilities of conservation is poorly mapped in the models, as are the implications of different consumption patterns. Several studies of the potential for conservation in particular countries (UK, US, Sweden) have indicated that this GNP-Energy link is considerably more flexible than the global studies have indicated. Other studies for individual countries show that consumption patterns have a major impact on long term energy demand. At the same time those changes in the North that would have substantial impacts on the Energy-GNP link probably would require rather strong government policies and intervention. Whether various interest-groups would accept such new roles for the government or not is in itself a major area of uncertainty.

However, there are other uncertainties than just the demand picture. Some of these are :

Uncertainties in oil supply, which include uncertainties in size of "proven" reservesm in future finding rate cost of off-shore and deep off-shore, cost impact and timing of advanced recovery methods, costs and timing of unconventional oil (tar sand, shale etc).

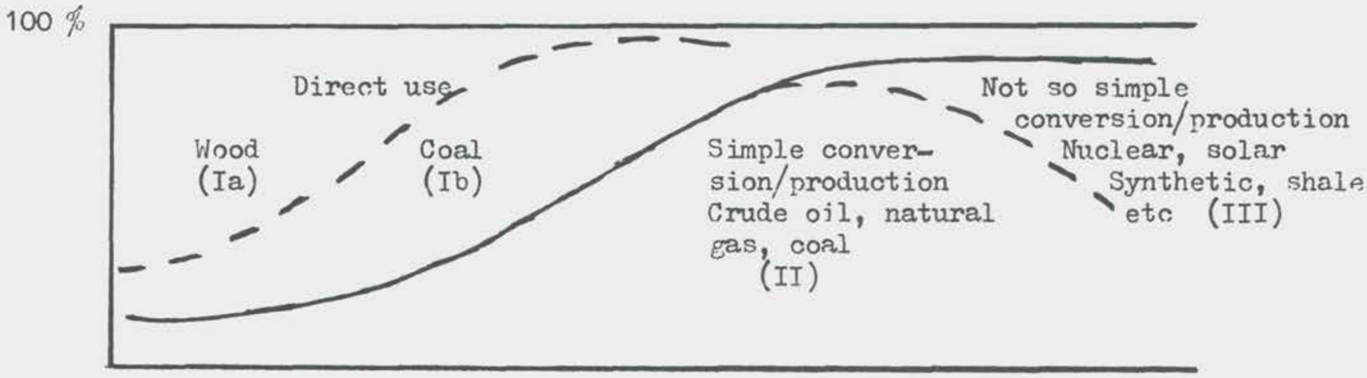
Uncertainties in coal and nuclear energy, mainly in the area of how rapidly they can expand (coal), costs, environmental impacts, public acceptance (nuclear) etc.

Political uncertainties when it comes to the role of environmental considerations, government/industry relationships, resistance towards nuclear power, and last but not least OPEC production policies.

The author believes that the uncertainty itself is an important ingredient in the energy picture. There is also a tendency in times of uncertainty to make decisions incrementally and thus rely on existing systems. Long term alternatives generally suffer. The net impact of uncertainty tends to be postponement of large scale investments with high (and uncertain) capital costs and long lead-times and thus heavier reliance in technologies with short lead-times and predictable costs. This "swing technology" happens to be oil. We shall return later to the prospects of the future oil supply.

So far the discussion has focussed on the near-term, i.e. the rest of the century. Beyond this lies the time period when oil and gas will have to be gradually replaced by other energy sources. The long term alternatives here are coal, nuclear energy (breeder) and solar, and it is yet too early to decide whether one or more of these alternatives are feasible or unfeasible. Strong cases can be made for and against all these alternatives, and the only reasonable policy is to try to keep all options open. Problems and conflicts of such policies are discussed elsewhere (Lönnroth, 1978). However, the transition away from oil is much more than just a change in fuel. Figure 2 illustrates four phases in the global energy use and three transitions between the phases :

- from a wood-dominated (phase Ia) to a coal dominated (phase Ib)
- from a coal-dominated to a oil/gas dominated (phase II)
- from oil/gas to something else (phase III)



The first transitionm from wood to coal, was made by the population in the now industrialized countries at the stage of industrialization and marks the institutionalization of energy supply (the change from subsistence to market economy). Energy thus became identified as a commodity of its own. This transition was by and large made by private initiative, and a large number of (coal) industries were established. The majority of mankind still has to pass through this transition. The second transition (from coal to oil and gas) marks the internationalization of energy supply and the emergence of worldwide corporations with an intricate set of interrelations. The coal industry was restructured and nationalized in many countries. Parts of the population in the LDC's have also made this transition. The third transition is the one which the developed economies in the world as a whole will have to make during the next 2-4 decades. The change from simple conversion/production systems to more complex ones have profound impacts on lead-times, mechanisms for raising capital and financing, the need for long term planning and coordination, environmental impacts etc and therefore also mark the emergence of the national governments as very important actors alongside and together with the hitherto rather independent private corporations that have organized energy supply. This has been analysed more in detail for Sweden (Lönnroth, 1978).

The less developed countries are right now in all phases. Part of the population still has to make the first transition, into the phase where energy is a market commodity. Another part has already made this transition and is relying on commercial fuel (wood, charcoal, coal, etc) for direct use in heating and cooking. And a third part has passed through the second transition into the phase of dependence on oil, gas, electricity etc in the same way as the population in the developed countries. An important question is therefore the relative timing of the different economies in the world in this third transition, away from oil and gas. Some argue that the developed countries have the best opportunities to pass quickly into the third stage (phase III) and thus rely more heavily on synthetic fuels, large scale deployment of nuclear energy etc. They would, by doing this, leave the more easily used oil to the less developed countries, thereby removing at least one bottleneck of their development. Others argue that the LDC's should try to pass through or bypass the second stage as quickly as possible and instead use more advanced and sometimes also capital intensive technologies such as solar energy etc. There seems to be general agreement that the North and the South have to choose complementary paths - there is not enough oil and gas around for both to depend for any longer time on the technologies of the second stage.

ENERGY ISSUES IN THE SOUTH

Historically the LDC's have increased their share in the global use of commercial energy from 2% in the year 1900 to 7% in 1950 and 17% in 1974*. Nevetheless the South is treated in rather broad-brush terms in the studies mentioned above. Only a few studies have looked more in detail at the LDC's and their energy demand. Table 2 gives some figures.

Table 2. Energy demand in LDC's (excluding OPEC) and the world (outside centrally planned economies) in the year 2000.

Study	World energy demand (mbdoe) (Excluding centrally planned economies)	Commercial energy demand in LDC's in 2000 (MBDOE) Total	Oil
BNL**	-	26	14
WAES	160-207	27-36	
WEC-I	160-207	35-48	
WEC-II	180	68	

The methods used in these studies are essentially the same, and the parameters are summarized in BNL (1978). The parameters used are economic growth, income elasticity of different forms of energy and an (aggregate) price elasticity. The WAES and the WEC-I study are based on the same assumptions for the developed economies, while the WEC-II study is based on different assumptions about income elasticity of energy (declining in the developed world from roughly 0.84 to 0.40 over a 40 year time period). The calculated energy demand of the LDC's are rather modest compared to the overall demand, but nevertheless substantial on an absolute level and comparable to the present US use.

Differences between less developed countries are large, however. The BNL-study is based on a somewhat more detailed breakdown, dividing LDC's in five groups as presented in Table 3. The numbers in this table have to be related to population figures as well.

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* These figures include OPEC

** Brookhaven National Laboratory

Table 3. Per capital energy use 1975 and 2000 in LDC's, US and Sweden.

Countries	GNP/capita ($), 1975	Per capita energy use 1975 (kgce)	Increase in per capita energy use 1975-2000
BNL Group*			
I	1120	1500	550
II	739	1230	655
III	225	710	190
IV	313	640	30
V	-	520	0
USA	7,900	11,000	2600-5300x*)
Sweden	8,700	6,200	1800xx*)

Although differences between developed and less developed countries still are large, it is also clear that differences between LDC's are increasing. Some countries are rapidly industrializing (group I) and a larger and larger segment of the population is living in conditions resembling those in the developed countries. In other countries the rate of population growth all but compensate for the economic and thus energy growth. At the same time the possibilities to introduce new energy technologies are intimately linked to social structure within the countries. It seems, therefore, more reasonable to look at broad social categories common to all countries rather than countries. The following is a very rough characterization.

The rural poor, who by and large live outside the monetary economy, have very limited access to capital, education etc and not infrequently live within a social structure where even meager surpluses through different mechanisms are channelled to the relatively more well-to-do. Energy is needed mainly for production and preparing of food and provided mainly by locally collected (and thus largely non-commercial) fuels (wood, dung etc). Animate energy also plays important roles.

The urban poor, who live in the very rapidly growing slum areas around major cities.
The driving forces behind the urbanization are complex, but can probably be traced back both to the relative opportunities in the urban areas and to the conditions of the rural areas and changes in agriculture technology, in turn at least partly related to the social structure in these areas. The economy of the urban poor is more dependent on the urban developed class, and the energy characteristics lie somewhere between the more modern urban developed and the traditional poor. According to one study (8) the urban poor tend to aspire for the consumption and thus energy pattern of the more well-to-do and thus move up the social ladder. Traditional fuels (fuel-wood, charcoal) are used alongside with more modern. Population densities are such that energy technologies dependent on grids (gas, electricity) are feasible, but lack of purchasing power means that load factors are low and energy costs high, thus perpetuating the situation.

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* The actual grouping of countries are presented in the annex.

x*) IEA study (1976), stating that this is a reduction compared to earlier studies.

xx*) National Swedish Industrial Board (SIND).

ENERGY ISSUES IN THE SOUTH

Historically the LDC's have increased their share in the global use of commercial energy from 2% in the year 1900 to 7% in 1950 and 17% in 1974*. Nevetheless the South is treated in rather broad-brush terms in the studies mentioned above. Only a few studies have looked more in detail at the LDC's and their energy demand. Table 2 gives some figures.

Table 2. Energy demand in LDC's (excluding OPEC) and the world (outside centrally planned economies) in the year 2000.

Study	World energy demand (mbdoe) (Excluding centrally planned economies)	Commercial energy demand in LDC's in 2000 (MBDOE) Total	Oil
BNL**	-	26	14
WAES	160-207	27-36	
WEC-I	160-207	35-48	
WEC-II	180	68	

The methods used in these studies are essentially the same, and the parameters are summarized in BNL (1978). The parameters used are economic growth, income elasticity of different forms of energy and an (aggregate) price elasticity. The WAES and the WEC-I study are based on the same assumptions for the developed economies, while the WEC-II study is based on different assumptions about income elasticity of energy (declining in the developed world from roughly 0.84 to 0.40 over a 40 year time period). The calculated energy demand of the LDC's are rather modest compared to the overall demand, but nevertheless substantial on an absolute level and comparable to the present US use.

Differences between less developed countries are large, however. The BNL-study is based on a somewhat more detailed breakdown, dividing LDC's in five groups as presented in Table 3. The numbers in this table have to be related to population figures as well.

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* These figures include OPEC

** Brookhaven National Laboratory

Table 3. Per capital energy use 1975 and 2000 in LDC's, US and Sweden.

Countries	GNP/capita ($), 1975	Per capita energy use 1975 (kgce)	Increase in per capita energy use 1975-2000
BNL Group*			
I	1120	1500	550
II	739	1230	655
III	225	710	190
IV	313	640	30
V	-	520	0
USA	7,900	11,000	2600-5300x*)
Sweden	8,700	6,200	1800xx*)

Although differences between developed and less developed countries still are large, it is also clear that differences between LDC's are increasing. Some countries are rapidly industrializing (group I) and a larger and larger segment of the population is living in conditions resembling those in the developed countries. In other countries the rate of population growth all but compensate for the economic and thus energy growth. At the same time the possibilities to introduce new energy technologies are intimately linked to social structure within the countries. It seems, therefore, more reasonable to look at broad social categories common to all countries rather than countries. The following is a very rough characterization.

The rural poor, who by and large live outside the monetary economy, have very limited access to capital, education etc and not infrequently live within a social structure where even meager surpluses through different mechanisms are channelled to the relatively more well-to-do. Energy is needed mainly for production and preparing of food and provided mainly by locally collected (and thus largely non-commercial) fuels (wood, dung etc). Animate energy also plays important roles.

The urban poor, who live in the very rapidly growing slum areas around major cities.
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* The actual grouping of countries are presented in the annex.

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xx*) National Swedish Industrial Board (SIND).

The urban developed class could be said to represent the enclave of the developed countries within the LDC's, where standard of living, consumption patterns, possibly also consumer values are essentially those of the well off in the developed countries. This class depends on an industrial infrastructure and the gradual development of markets for those industries. Consumption of indirect energies are high (processed food, industrial goods etc). High-grade fuels, electricity etc produced by oil, coal (nuclear to some small amount), hydropower etc are important.
The social, economical and political conditions of the three groups are so different that one may very well speak of different societies, partly emmeshed in and partly independent of each other. The relative proportion of these societies differ between countries.

Acknowledging all the differences we shall nevertheless attempt to make a brief characterization of the LDC energy situation. It seems to be :
highly dependent on traditional fuels, particularly for the rural population but also for parts of the urban poor. The dependence varies between countries, but roughly 1.2 billion people live in countries which use traditional fuels to more than 50 % of their energy supply.

highly dependent on oil when it comes to commercial fuels. Only a few LDC's use coal or hydropower in any great part due to high transport cost and low level of electrification (India and China are exceptions in the coal case). There is a tendency that the less developed the countries are the more important is oil relative to other commercial fuels. This oil dependence is moreover concentrated to lighter grades (LPG, kerosene, gasoline, light fuel oil etc) and to a large part used for transportation.

low overall energy conversion efficiency, which holds for both uses of traditional fuels and for commercial fuels. Traditional fuels in rural areas are typically used for cooking, and the overall efficiency of cooking equipment is low compared both to what could be the case and compared to industrialized countries. In the same way since railways (and shipping) is much less developed the relatively less energy efficient road (automobile) and air transport systems are more dominating than in developed countries.

high costs of energy. Individuals and households in the LDC's frequently pay more for their energy both relative to their income and relative to costs in developed countries. (According to one study a barrel of oil cost $132 in Tchad even before the oil crisis). This depends on high transport costs, low load factors of e.g. electricity systems etc. The fact that solar electric technologies are regarded as competitive in certain LDC's application only comes from the fact that conventional electricity is much more expensive (due to high costs of electrification and low load factor) than in developed countries.

The energy situation in LDC's is obviously only a mirror of the overall economic, cultural and socio-political situation. The critical question is therefore to what extent energy strategies in general. One might guess that such a separation - and thus adaptations to new energy realities - would be easier the more institutionalized and professionalized the energy supply system is. It may, for example, not at all be possible to change the energy situation in the rural areas of the LDC's without changing the overall agricultural pattern.

Given the infrastructure of the LDC's oil-based fuels have great advantages, since they are easy to transport and handle, usable for many purposes and also possible as substitutes for traditional fuels. Coal, which is also easy to use has much higher transport costs. At the same time the large dependence on traditional and/or noncommercial fuels such as cow-dung, wood, charcoal etc is problematic. The capacity of the ecosystem to provide these fuels is, while they nominally are renewable, also limited. Excessive production threaten the ecosystem and thus the yield in many areas, leading to soil erosion etc. Large groups in the LDC's have therefore been caught in a trap between the too high dependence on noncommercial fuels and the difficulty in replacing them by anything else other than oil.

This discussion opens up a series of questions (large and interrelated) on how the issues discussed are linked to LDC development patterns in general and actions and non-actions in the North in particular. Some of these questions are :

- What are the mechanisms for substituting traditional fuels with commercial fuels in LDC's ?
- What role does cost of commercial fuels and overall economic growth in LDC's play in this substitution ?
- To what extent is overall economic growth in LDC's dependent on the economic health of the North ?
- Are (the energy intensive) consumption patterns in the North implementable on a large scale in the South ?
- What are the energy implications of different development patterns in the South ?
- Is oil more critical for the economic development in the South than it is for the economic growth in the North ?

These are large areas, but the author nevertheless believes that they have to be touched upon. With respect to the North the following topics seem particularly relevant :

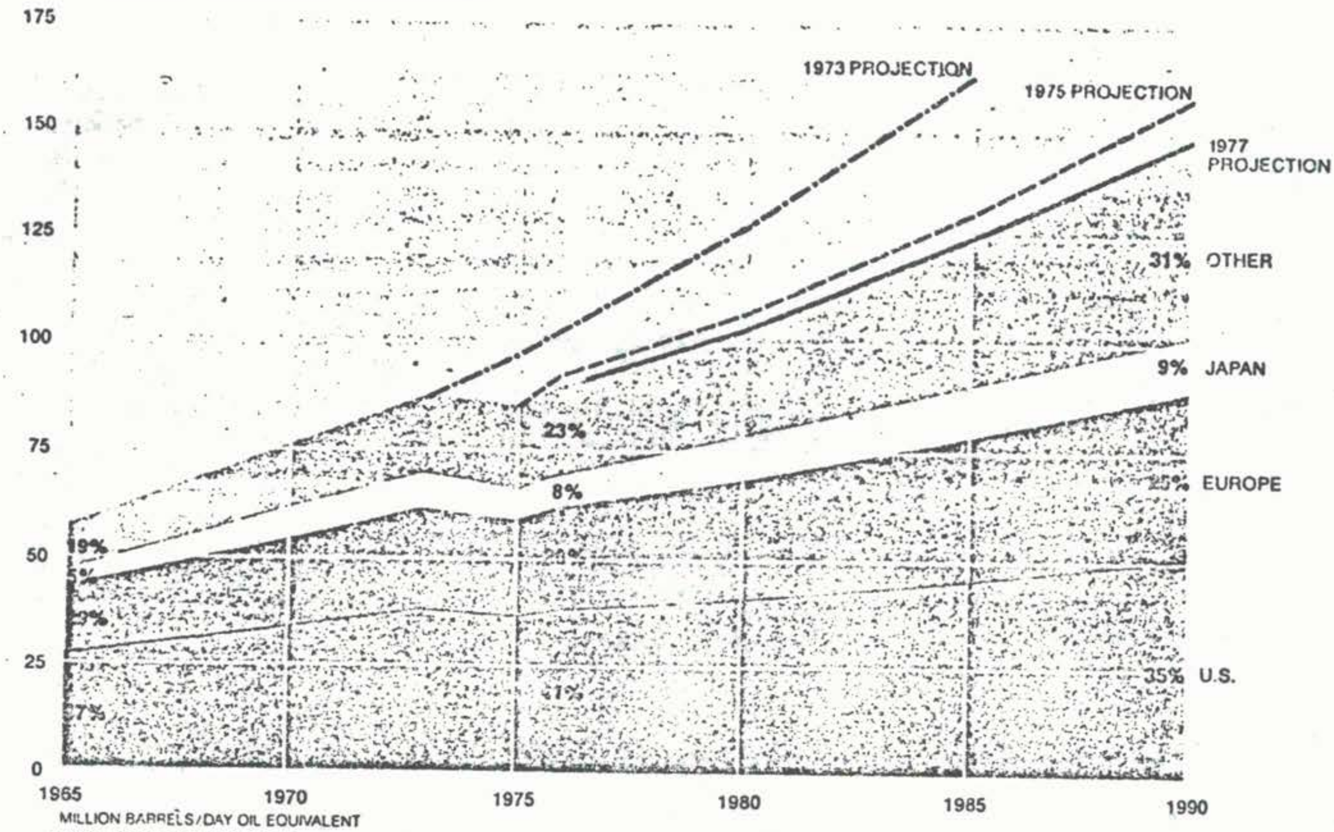
- global oil supply, including the role of small deposits in the LDC's
- future economic growth in the North, trade patterns and implications for LDC's
- energy policies in the North and their implications for the South.

THE GLOBAL OIL SUPPLY

As mentioned earlier many studies have predicted that oil supply will become limited fairly soon. How soon depends on demand growth and possibilities for expanding supply. Whether the supply limitations will have serious consequences or not - or indeed lead to serious price increases - will depend on the timing of alternatives to oil. Figures 3 and 4 taken from Exxon's latest annual study give the situation in a nut-shell. Exxon also notes :

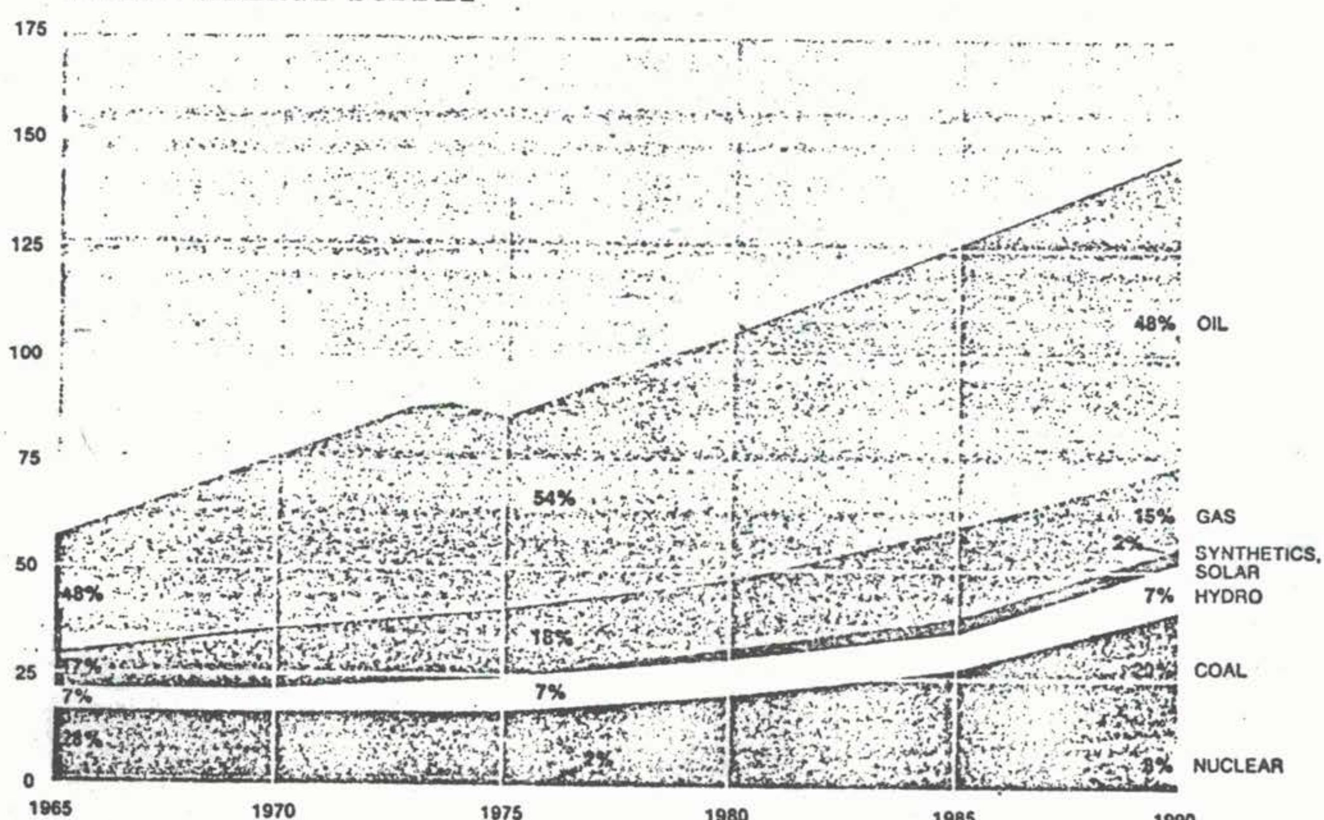
> "The outlook for energy demand is affected by the economic outlook. Given the ± 0.5 percent per year which might be a reasonable range of variability in the economic growth projection, the related range of non-Communist energy demand would be about ± 5 million b/d oil equivalent in 1985, or ± 9 million b/d oil equivalent in 1990, assuming the energy/GNP relationship were to remain unchanged in a higher or lower economic growth environment. Much of this variability would be reflected in the demand for oil".

WORLD* ENERGY DEMAND



MILLION BARRELS/DAY OIL EQUIVALENT
*EXCLUDING COMMUNIST AREAS

WORLD* ENERGY SUPPLY



MILLION BARRELS/DAY OIL EQUIVALENT
*EXCLUDING COMMUNIST AREAS

The time perspective of the oil supply system should be compared with the leadtimes of individual operations from access to commercial production. Table 4 comes from Exxon and is probably on the optimistic rather than pessimistic side.

Table 4. Leadtimes according to Exxon

	Years
Oil and gas	
US lower 48 states onshore, discovered Mid-East	1/2–2
US Gulf coast off-shore	3–4
North Sea off-shore, undiscovered Mid-East	5–10
Frontier Areas: off-shore US, Africa, Far East, Latin America	6–12
Coal	4–8
Synthetics	
very heavy oil (tar sands)	6–9
shale oil, coal (liquid), coal gas	7–10
Nuclear	
US	8–12
Europe, Japan	6–10

Leadtimes are long – and above all increasing – due both to inherent properties in the technologies such as increasing scale, increased complexity, more difficult operating environments but also due to increasing difficulties in resolving public policy issues especially in establishing a balance between environmental and energy considerations. The long leadtimes mean that the maximum energy supply up to mid and late 80's already is largely determined.

One of the important characteristics of the world of oil supply system is the relative rates of discoveries and production of oil. This is shown in Figure 5. According to Exxon, it is considered likely that the average of discovery up to 1990 will fall somewhere between 12–18 billion barrels a year, while production is expected to increase from roughly 15 billion barrels a year 1975 to roughly 25 billion barrels a year in 1990. The average reserve to production ratio is thus falling, and the total growth of oil production sooner or later will taper off "..... and possibly reach a plateau before the end of the century".

The ultimately recoverable conventional crude oil resources have been estimated in a number of studies. A Rand study (1978) summarizes the picture as given in Table 5.

Table 5. Crude oil, billion barrels.

Already produced by the end of 1975	335
Proven and probable reserves	676
Future discoveries	263–555
Further development of and additional recovery from known fields	420–730
Ultimately recoverable conventional crude oil	1700–2300

The geographic distribution is given in Table 6.

Table 6. Estimated ultimate conventional world crude oil resources by region (In billions of barrels)

Region	Known	Potential	Total
North America	179.8	100–200	280–380
South America	68.4	52–92	120–160
Western Europe	24.6	25–45	50–70
Eastern Europe/ Soviet Union	102.4	63–123	165–225
Africa	75.6	45–94	120–170
Middle East	509.9	350–630	860–1140
Asia/Oceania	50.8	54–104	105–155
Total	1011.5	688–1288	1700–2300

There are of course possibilities that the total amount will exceed 2,300 billion barrels but nevertheless the overall picture seems reasonably clear. The global oil supply system is changing according to Figure 6 (Grenon, 1978) and becoming more and more complex at the same time as oil is becoming more rather than less important to a growing number of people.

GIANT FIELD →	MEDIUM FIELDS →		SMALL FIELDS
5.10^9 bbl	500.10^6 bbl	50.10^6 bbl	5.10^6 bbl
700.10^6 t	70.10^6 t	7.10^6 t	$0.7 \cdot 10^6$ t

ONSHORE → OFFSHORE → DEEP OFFSHORE

"GOOD" OIL (80–25 API) → DIFFICULT OIL (25–10 API) → "BAD" OIL (10–7 API, TAR SANDS) KEROGEN, OIL SHALES)

Fig. 6

It should be added that many undeveloped but identified oilfields contain environmentally more problematic oil (e.g. high sulphur) implying increasing complexity also of refinery operations.

The net effect of all this is increased costs of production. Table 7 gives some figures from BP (1978).

Table 7

Conventional crudes	1978 dollars/barrel
Arabian Light, excluding producer government take	1–4
North Sea	6–12
Syncrudes	
Shale oil	15–23
Heavy oils (in-situ)	12–20
Tar sands	14–25
Coal liquefaction	15–30

This means that the major part of the oil today is produced at costs substantially below world market prices (both in the US, USSR and the Mid East) and at the same time the new oil that have to come onstream in order to postpone the peaking of total oil production have costs at, above or sometimes substantially above the world market price.
The price is set in a process where requirements of government revenues in OPEC, the fear of inflationary and recessionary consequences in developed countries, the need for oil conservation and also rapid development of new oil are mixed with uneasy feelings about how the political stability of main oil producing and consuming countries are affected by economic conditions in turn partly depending on oil costs.

The global oil supply system moreover tends to become more and more fragmented and less coordinated. The oil supply has previously been largely coordinated by the oil companies in order to plan production, avoid gluts, stabilize prices and thus (among other considerations) reduce uncertainties for investments. The rather rapid involvement of national government in producing countries – in themselves necessary

because the large impacts on the respective economies - have made processes of coordination and thus avoiding gluts and instability of oil prices more complicated.
To make any forecasts of future world oil prices therefore seems to be rather risky. The prophesies for the 90's range from a doubling price in real terms to a constant one.

What about the role of the LDC's in the global oil supply system ? They are affected in several ways.
Firstly many LDC's have substantial areas of sedimentary basins. The possibilities of successful oil exploration in LDC's have therefore been the subject of much speculation. The oil industry tend to believe that the overall potential of the LDC's (outside the Mid East) is rather limited, but some experts outside the industry are more optimistic.
The World Bank has recently announced a program to stimulate drillings in LDC's. The oil industry, with its high costs for exploration and uncertainty about its outcome, have generally been reluctant to invest in countries where the terms of concessions of the governments have not been regarded as predictable and/or favorable enough. The net result is that many prospective areas have not been drilled. The World Bank has - among many others - recognized the problems and offered to play a "third party" role in the negotiating between industry and host government. The net effect would be to increase the spectrum of possible repercussions to a government which chooses to unilaterally re-negotiate a previous deal.
The topics raise the fundamental problems of what constitutes reasonable and fair deals between governments and large corporations. This is not the place for elaborating on this problem, but it seems quite clear that governments - and the public - in many Northern countries - e.g. Britain and Norway - would never accept the conditions that many Southern governments have had to accept.
Secondly, the LDC demand for oil products is much more oriented towards lighter grades, and the market for heavier fuel oils is more limited. It is quite possible (in fact likely) that the price of the lighter grades will increase much more rapidly than crude oil. The mechanism for this is that conservation of oil in the developed countries to a large extent is oriented towards heavy fuel oil (used in processing industry and electricity) where it can be replaced by e.g. coal, while the conservation of lighter fuel oil in the transportation system and in individual homes tends to be more difficult to manage. Converting (cracking) heavier oils into lighter costs money as well. A more detailed analysis of the situation for the LDC's should therefore take the markets for different grades into account.
Thirdly it should be noted that oil production in a less developed country does not mean independence or isolation from the global oil situation. Properties of the oil, the sizes of the markets for different grades and the costs of refining will generally mean that the crude oil will have to be exported and refined in other areas and that the refined products will be imported. Oil in many LDC's should perhaps be seen more as sources of hard currency than as sources of energy. This does not necessarily diminish the value of findings, but it does add some new dimensions.

WORLD ECONOMIC GROWTH, TRADE PATTERNS, LDC'S AND ENERGY

A deeper analysis of the energy condition for the LDC's has to be based on some assumptions about the world economy and its prospects. This section is intended to give some food for thought about these problems. We shall look at the implications of a low and a high case of economic growth and then discuss to what extent the energy situation reinforces either tendency.

A low economic growth in the industrialized world would probably reduce the pressure on the oil market, but there would also be substantial difficulties in raising the capital that will be needed in order to eventually reduce the dependency on cheap-to-produce oil. Pay-back of debts of oil importing countries will add to these problems, further reducing the growth of personal income. Continued high levels of unemployment are likely to strengthen the inherent tendencies of protectionism and regionalizing trade patterns (one might even say that free trade is only possible under conditions of high economic growth).

Possible devaluations to increase competitiveness and continued instability of the world monetary system will increase uncertainties about trade and export. At the same time a strengthened IMF may very well impose severe conditions on many countries that have to rely on its services.

The net impact of all this may very well be reduced possibilities for economic growth also in LDC's and possibly also trade patterns that tend to link individual LDC's or groups of LDC's to particular Northern blocs (US, Common Market, Japan).

High economic growth should make the above mentioned problems more easy to handle. It should be much easier to raise capital for the necessary investments in the energy sector, and the turnover of energy using processes, plants and commodities may speed up the introduction of more energy efficient processes. This should make it possible to reduce the energy/GNP-ratio more rapidly than in the case of low economic growth. At the same time increased economic growth is by itself likely to speed up the spread of energy intensive consumption patterns (suburban living, leisure patterns etc) to even larger groups of the population. If the latter tendency should not dominate over the former rather strong government policies are likely to be necessary. Whether these policies also are likely to be implemented is another matter, but a critical one.

High economic growth is also likely to ease the situation for many LDC's, specially the rapidly industrializing ones. The tendency towards protectionism should be much weaker.

These cases are undoubtedly idealized cases. The latter is definitely the more desired one, but the former seems to be regarded as the more likely one. Many mechanisms and theories are put forward in this argument: Kondratieff cycles (the long waves of capitalism), shift in values in developed countries towards less growth, unequal strength and independence of labor unions (strong in Europe, weaker in US, almost non-existent in many LDC's), increasing mis-match between economic interdependence and lack of coordinated economic policies in developed countries, differing priorities over inflation, unemployment etc, instability of world monetary system, etc.

The rapid growth of the 50's and the 60's tend to be regarded as an exception rather than as a rule. It is, however, rather difficult to say to what extent the pessimistic mood is realistic or not, but certainly it tends to be self-fulfilling.

The role of energy supply and oil in particular is probably rather weak compared to these tendencies, but it does reinforce the depressive tendencies and also amplify the regional differencies. Some of these mechanisms:

- Many industrialized countries run substantial balance-of-trade deficits due to high oil import bills. This had lead governments to try to hold back imports through deflationary policies, thus adding to the recessionary forces. The fact that some governments in developed countries have balance-of-trade surpluses has reinforced the problem.

- The deficits in the balance-of-trade amounts to a huge surplus of petrodollars recycled through the international banking system and reinvested in places with good growth prospects. The advanced LDC's (the so-called NIC's, Newly Industrialized Countries) are among these recipients, and due to lower labor costs etc industries in these countries are increasingly able to outbid industries in developed countries. This adds to the balance-of-trade deficits in these developed countries (particularly in Western Europe).

- Different costs of energy in different regions adds to the differences in competitiveness between developed countries. The US have much lower energy prices than the rest of the world, and this is sometimes seen as a competitive advantage.

The net tendency of all this is to reinforce the centrifugal tendencies in the world economy, splitting it up into several blocs around the US, Western Europe and the Mediteranean, The Far East around Japan. If the trend is continued for any length of time it is quite likely to have profound impacts on LDC growth prospects and thus energy requirements. In particular oil producing LDC's may also find themselves increasingly tied to strong developed but oil importing countries. It should be added that these somewhat pessimistic projections are not inevitable. The main conclusion is, that any study about the energy requirements of the LDC's must be based on some assumptions about the general economic climate in the world, and that the pessimistic climate described above is just as likely (or more likely) as the more desired one. This thus raises the question of resilient strategies, i.e. whether development strategies in LDC's can be found that are inherently less vulnerable to the international economic development and the actions (and non-actions) of the developed countries.

ENERGY POLICIES IN THE NORTH

In this section we shall dwell somewhat upon the problems of arriving at strong energy policies in Northern countries. There seems to be large agreement on the need for a transition away from oil in the Northern countries. This agreement masks, however, some rather deep disagreement over what the replacement of oil should be and also what the main mechanisms for guiding the transition should be.

A policy which advocates primarily a dependence on conventional alternatives (oil, coal, gas, nuclear), electrification and synthetic fuels but a much smaller dependence on conservation would put the main emphasis on "clearing the ground" for existing energy industries, streamlining environmental standards, procedures for siting decisions etc. The role of the government would mainly be to back up the supply industry. With less emphasis on conventional alternatives and more emphasis on conservation (cogeneration and thermodynamic cascading, less electrification, low grade heat storage, retrofitting of buildings etc) and stimulation of solar technologies (heating, dispersed electric etc) the role of the government would be very much different. The inherently more dispersed technologies of conservation and solar and the need for much more careful integration between supplier and user would require a different role for national and local governments and thus also for the energy industries and particularly the utilities. These questions cannot be confined to the energy sector but have to be perceived in the context of more general controversies of the role of governments in post-industrial economies and the question of intervention in and shaping user-producer relationships.

In the words of the Trilateral Commission on Energy Policy in the US:

> "If the society cannot agree on such fundamental questions as an acceptable level of economic growth, a desirable distribution of income, the respective roles of corporations and government in managing the economy, it is unlikely that it can resolve issues of energy prices, environmental trade-offs, and the appropriate degree of government regulation".

But more issues than just government/industry relationships are involved. Some have argued that the issue at heart is not only - or merely - economic and environmental but also very much the structure of society itself.

A recent study over the public attitudes towards nuclear power concluded:

> "Part of the opposition to nuclear energy stems from concerns which go beyond technologies to the social and political institutions they imply. Our research suggests that the nuclear controversy is providing an arena in which fundamentally different philosophies are being debated. These philosophies, in turn, imply alternative visions for the future development of society.

In general, technologists have been surprised at the strength of public reactions against nuclear energy. Social scientists, in turn, have been equally surprised at the reluctance of technologists to accept the validity of public concerns about social issues as being quite distinct from the technical realities. It has been said that the fundamental concept in the physical sciences is energy and, in this same sense, power is the fundamental concept in the social sciences. If there is a central issue in the nuclear controversy it is personal and political power and public participation in the control of that power."

While this study is concerned only with nuclear power, there is no doubt that many other energy technologies have experienced essentially the same climate.

These studies should mainly be seen as reminders that the issues of energy policy cannot be isolated from the more general social climate and the issues that are important in the minds of the public. It is how technologies of energy supply are perceived to fit into discussions on government/industry relationships, producer/consumer relationships, role of economic growth and income distribution, control over technological choices, confidence in and legitimacy of established institutions that will shape the transition away from oil. The question of how many cents, pennies, centimes or pfennig a kWh costs is in this respect a secondary question.

These concerns and conflicts exist to a varying degree in most developed countries. But there is no question that the single most important country, the US, is also the one that seems singularly most inept in handling these questions. The failure of the US to achieve an energy policy which is likely to reduce oil imports substantially is adding to the strain that exist for other reasons between developed countries. The US on the other hand is the only country that can substitute the lack of comprehensive domestic energy policy with a strong foreign policy, securing imports from oil exporting nations by various means.

CONCLUDING COMMENTS

The aim of this paper has not been to try to give definite answers to what the energy link between North and South looks like, but rather to raise a number of questions and issues. Many important questions have not been raised, such as the role of nuclear energy in LDC's and the non-proliferation policies in some Northern countries. Nevertheless it is a rather grim picture that has been painted, and the main issues in this picture seem to be :

- is it reasonable to assume that there is not enough oil available during the next two decades to fuel a high economic growth of both the North and the South and that thus either group has to plan to deliberately get out of oil ?

- is it reasonable to expect that the coming 10-20 years will have substantially lower economic growth than the previous 20 years ?

- if this is the case, is it reasonable to expect a combination of free trade patterns (or reinforcing of these patterns) or is it more reasonable to expect a growing tendency towards protectionism, bilateral agreements and regional, inwardlooking cooperation (the self reliant North) ?

- is it reasonable to assume that oil is the single most important commercial fuel for the majority of the LDC's and that other commercial fuels (coal, gas) are an order of magnitude less important ?
- is it reasonable to assume that the demand for oil in the LDC's will be more directed towards lighter grades also in the future ?
- oil is more easily replaced in the North than in the South, where capital intensive technologies such as gas, electrification etc are more easily introduced. Is it reasonable to assume that this will take place ?
- what is a fair deal between governments and international industry in developing indigenous oil resources ?

REFERENCES

BP. Briefing paper. London 1978.

Brookhaven National Laboratories. Energy needs, uses and resources in developing countries. Policy Analysis Division. March 1978.

CIA : "International Energy Situation: Outlook to 1985". Washington, April 1977.

EPRI : Outlook for world oil into the 21st century. Prepared by Petroleum Industry Research Foundation. May 1978.

Exxon World energy outlook. April 1978.

Grenon Michel: The unknown future energy demand. September 1978.

Grenon, M.: Three paths to costly oil. Power Engineering. October 1978.

IEA: "Energy Policies and Programmes of IEA countries. OECD, Paris 1978.

Institute of Energy Analysis. US Energy and Economic Growth 1975-2010. Oak Ridge, September 1976.

"International Energy Supply" Perspective from the Industrial World. Rockefeller Foundation. May 1978.

Lönnroth, M.; T.B. Johansson; P. Steen : Sweden beyond oil - Nuclear commitments and solar options. Secretariat for future studies, Stockholm 1978.

Lönnroth, M. : The oil peak and beyond - scoping out a study on European transitions into new energy orders. Secretariat for future studies, Beijer Institute, September 5, 1978.

OECD. "World Energy Outlook". Paris 1977.

Richard Nehring, RAND. June 1978. Giant oil fields and world oil resources.

Sawhill, John C, Maull, Hanns W, Oshima Keichi: "Energy: Managing the Transition". Draft Report to the Trilateral Energy Task Force. June 1978.

ENERGY RESOURCES IN KENYA AND THEIR ENVIRONMENTAL IMPACTS

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SUMMARY

This paper reviews the different energy sources available in Kenya and their environmental impacts.

INTRODUCTION

Energy is an essential commodity of any society and may be crudely used to indicate the standard of living of that society. For example Fig. 1 shows the relationship between the per capita Gross National Product (G.N.P.) of 35 countries of the world and their respective per capita energy consumption in 1971. The correlation is high despite different political systems, climates etc., and the disparity between developed and developing countries is conspicuous. Kenya is among the lowest 50 nations of the world at present (Githinji, 1978).

PRIMARY SOURCES OF ENERGY IN KENYA

Kenya's requirements for commercial energy for the years 1970 to 1977 are shown in Table 1 and as percentage figures in Table 2. The heavy reliance on petroleum products is to be noted, accounting for 85% of the total in 1977. The growth in consumption of all fuel types has been of the order of 8% per annum, greater than the growth of G.N.P. which has been approximately 6.5%. It is interesting to observe that import of crude oil reached a peak in 1974 and then declined, although the consumption of petroleum products in Kenya has continued to increase through to 1977 i.e. less has been exported. The refinery at Mombasa has a potential throughput of 4 million tonnes per year, so was only operating at 63% capacity in 1977. All the crude oil and coal and coke are imported, as is 30% of the hydroelectricity from Uganda. Not shown in the tables is the consumption of firewood and charcoal as accurate data is difficult to come by. However it is estimated from different reports that between 70% and 80% of the total energy consumption in Kenya is from this source, which is the primary fuel for the rural population. Similarly solar energy is not accounted for though extensively used for drying crops. There are very few biogas plants and windmills in the country.

The demands for energy by sector are estimated approximately in Table 3. The industrial sector includes agriculture and service industries and consumes 67.9%. The transport sector is entirely dependent upon petroleum products.

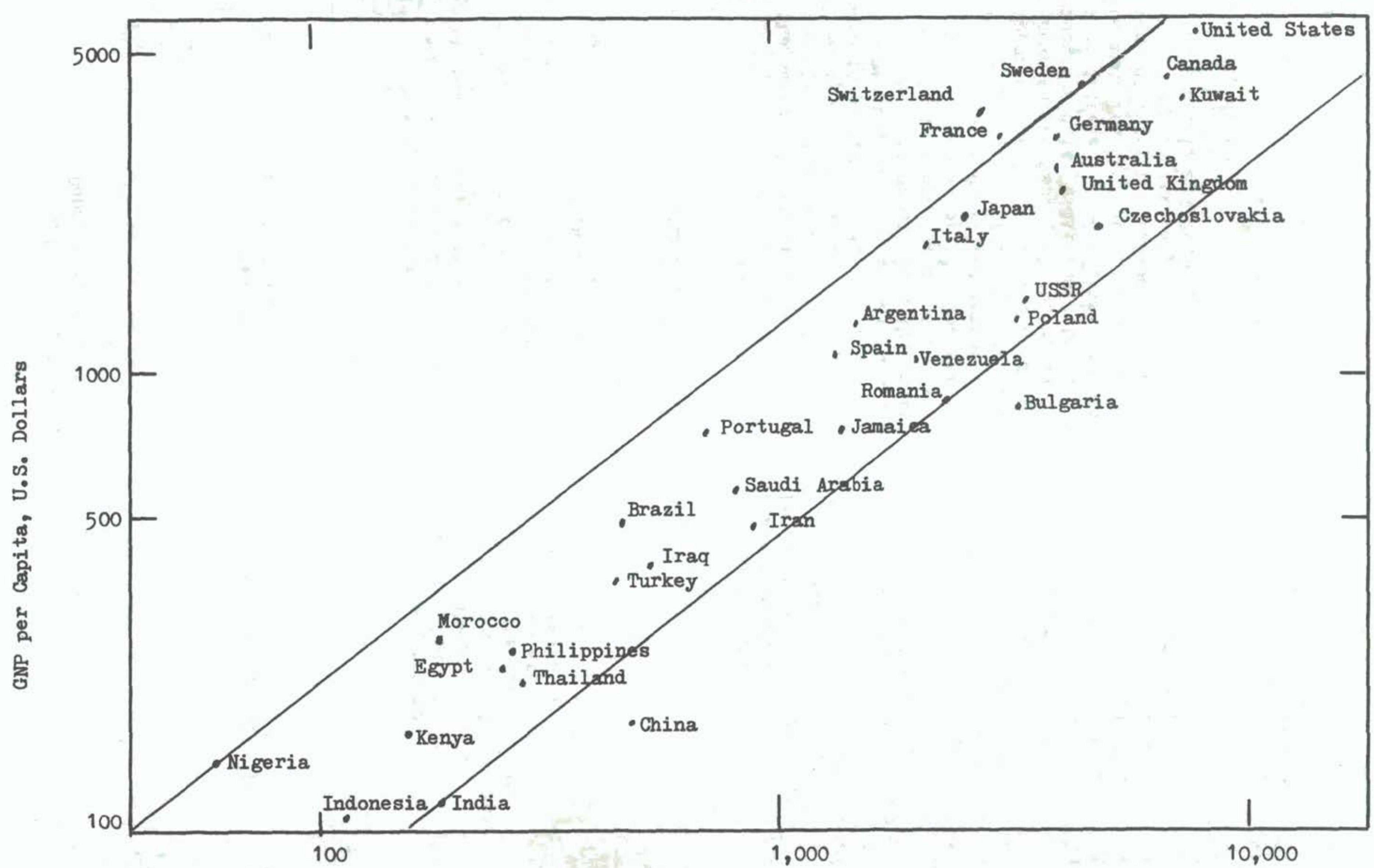

Figure 1. Per Capita Energy Consumption in 1971, Kilogrammes of coal equivalent.

Source: UNEP

TABLE 1: CONSUMPTION OF PRIMARY COMMERCIAL ENERGY IN KENYA

		1970	1971	1972	1973	1974	1975	1976	1977
Coal and Coke in tonnes x 10^3		83.0	82.7	40.4	71.4	66.6	45.8	64.1	62.6
Imported crude oil in tonnes x 10^3		2203.0	2538.4	2507.0	2695.6	2902.9	2824.9	2496.7	2551.5
Consumption* of petroleum products in Kenya in tonnes x 10^3		1043.2	1157.0	1288.3	1359.9	1352.7	1392.8	1563.5	1605.9
Hydro-electricity production in GWh	within Kenya	336.1	338.8	400.6	407.7	547.1	648.3	583.2	749.3
	Imported	247.2	293.4	283.2	302.4	296.0	260.8	241.9	271.8

* Difference is that exported to other African Countries.

Source: Singh (1978).

TABLE 2: PERCENTAGE PRIMARY COMMERCIAL ENERGY CONSUMPTION IN KENYA

	1970	1971	1972	1973	1974	1975	1976	1977
Coke and Coal	4.7	4.2	1.9	3.2	2.9	2.0	2.5	2.3
Petroleum products	84.0	84.7	87.0	86.1	84.5	84.8	86.5	85.3
Hydro-electricity	11.3	11.1	11.1	10.8	12.6	13.2	11.0	12.4

Source: Singh (1978)

TABLE 3: APPROXIMATE PRIMARY COMMERCIAL ENERGY CONSUMPTION IN KENYA BY SECTOR IN 1977

	PETROLEUM PRODUCTS TONNES x 10^3	ELECTRICITY GWh	COAL AND COKE TONNES x 10^3	AS %
Industry including service industries and agriculture	1029.3	1081.6	62.6	67.9
Transport	563.7	-	-	28.4
Domestic	12.8	303.5	-	3.7

PRIMARY ENERGY SUPPLY BY FUEL TYPE

Oil

Oil is imported from the Middle East and refined at Mombasa. The majority is then pumped by pipeline to storage tanks in Nairobi with further distribution by road and rail. The sales of petroleum products are given in Table 4 for the years 1970 to 1977, from which it can be seen that the growth of LPG, turbo fuel and gas oil has been higher than the average of 59%.

The importation of crude oil has a critical influence on the balance of payments situation in Kenya as may be seen from Table 5. Before the oil price rise of 1973/74 there was only a small deficit between the amount paid for the importation of crude oil and the amount recovered from exporting the refined products to other African countries. However the deficit has widened considerably and in 1976 the import of crude oil accounted for 24% of the total import bill of the country (Maitha, 1978). It now costs 5 times as much in 1977 to import slightly less crude oil than it cost in 1973 (Mathenge, 1978).

To date no oil has been discovered in Kenya though there has been an exploration programme since 1954 when the first licence was granted. Approximately 30% of the country is considered to have hydrocarbon potential, particularly in north east, and areas of the coast are now receiving attention. However only 14 wells in 25 years have been sunk (Owayo, 1978) due to the high cost of drilling which is undertaken by international firms. In monetary terms £10.84 has been spent between 1970 and 1976 for no return.

Coal

Most of the coal imported into Kenya is from Swaziland with a little from the U.K. It is used by industry to fire boilers and furnaces. Exploration for coal has also met with no success in Kenya. Traces have been found in the oil drilling programme but not in significant quantities. A recent 2 year search by an Australian Company in the South West sedimentary basin showed nothing.

Electricity

Electricity is produced by both hydro power and thermal power and is mainly distributed by the East African Power and Lighting Co. Ltd. (E.A.P.L.) a public limited liability company in which the government holds 54% of the share capital. There is some private generation of electricity by industry. The growth in electricity consumption is shown in Table 6 from which it can be seen that the growth rate is approaching 8% per annum. The consumption is supported by importation of hydroelectric power from Uganda. The hydroelectric schemes in Kenya are based on Tana River and with the commissioning of Gitaru in 1978 a further 145 MW was added to the grid. The Upper Reservoir Scheme is due for completion in 1981 providing an additional 40 MW. This will have the important effect of stabilising the water supply during dry seasons. In 1977 hydro-electric plants accounted for 50% of the total capacity as shown in Table 7.

TABLE 4: FUEL SALES IN KENYA IN LITRES

	1970	1971	1972	1973	1974	1975	1976	1977	% Growth
L.P.G.	12757	15177	18191	21029	21633	24161	26152	29607	132
Motor Spirit	235148	271148	292537	321041	311489	322145	332766	370556	58
Aviation Spirit	8442	6079	6979	7662	7786	8431	8281	8749	4
Turbo Fuel	224540	242422	278245	341769	318881	388405	407677	419906	87
Kerosene	58480	58191	68148	67003	68269	69511	69438	91977	40
Gas Oil	190027	248539	277792	302549	297899	305356	339437	371329	95
Diesel Fuel	42327	47075	50223	54845	47599	38339	52537	38424	-9
Fuel Oil	392073	419855	452652	432871	437098	473418	533775	541875	38
TOTAL	1163758	1308800	1444767	1548769	1510654	1629766	1770135	1850194	59

Source: Shell and B.P. Services Ltd.

TABLE 5: VALUE OF IMPORTS OF CRUDE OIL AND EXPORTS OF REFINED PETROLEUM PRODUCTS IN KENYA IN MILLION SHILLINGS

	1972	1973	1974	1975	1976
Imports of Crude Oil	- 418	- 446	- 1631	- 1916	- 2078
Exports of Petroleum products	389	433	921	1179	1395
Net Balance	- 29	- 13	- 710	- 737	- 683

Source: Central Bureau of Statistics.

TABLE 6: ELECTRICITY CONSUMPTION IN KENYA IN GWh

	1970	1971	1972	1973	1974	1975	1976	1977
*Hydro power	336.1	338.8	400.6	407.7	547.1	648.3	583.2	749.3
*Thermal power	246.5	286.2	333.6	385.6	322.6	304.4	528.9	364.0
Total	582.6	625.0	734.2	793.3	869.7	952.7	1112.1	1113.3
Imports from Uganda of hydro power	247.2	293.4	283.2	302.4	296.0	260.8	241.9	271.8

*Includes Industrial generation.

Source: Singh (1978).

TABLE 7: INSTALLED ELECTRICAL GENERATING CAPACITY

	1970	1971	1972	1973	1974	1975	1976	1977
Hydro kW	67450	71268	71268	70190	134080	166658	167080	168500*
Thermal kW	85763	114866	119566	132344	131933	97800	163008	170900*
% Hydro	44	38.3	37.3	34.7	50.4	63.0	56.6	49.6
% Thermal	56	61.7	62.7	65.3	49.6	37	49.4	50.4

Source: Statistical Abstract.

* Estimates.

Wood and Charcoal

Wood fuel is the most important single energy resource in Kenya. Approximately 90% of the population live in rural areas and depend on it for cooking and heating, and yet less than 3% of the country is gazetted as forest areas compared to a world average of 10%. The forest areas is assumed to be approximately 1.7 million hectares (Onyango, 1978). The rate of consumption of fuelwood was estimated to be 1.47 million cubic meters in 1975 (Earl, 1977). Another estimate by Muchiri (1978) is for 30 x 10^{12} kcal or 4.3 million tons coal equivalent. The rate of consumption far exceeds the rate of renewal. Typical wood burning stoves are less than 10% efficient and an increase in their efficiency would have an enormous impact on fuelwood consumption. The cost however must be kept to a minimum compatible with the low incomes of the rural population.

Charcoal production has been estimated variously at 170,000 tonnes (Githinji, 1978) or 310,000 tonnes (Onyango, 1978) in 1975 rising to 1.1 million tonnes (Kabagambe, 1976) by 1980. This last estimate would require 0.74 million hectares of trees, an increase of about 40% on current forest area. Rural afforestation is being pursued by the Ministry of Natural Resources and interest is being shown in fast growing trees such as Eucalyptus Globulus. However competition for land use is a seriously limiting factor. Only one third of Kenya's land area has a sufficiently wet climate and fertile soil for agricultural development and sustenance of forest. Kenya's ratio of arable land per head of rural population at 0.15 hectares is one of the lowest in the world (Pyle, 1978). Charcoal production in earth kilns is again only about 10% efficient, typically needing 12 m^3 of fuel wood for 1 tonne charcoal. Metal or brick silos could halve the quantity of fuel wood but the cost of kiln is important. Further improvements can be made in the traditional charcoal burning stove by better insulation. The charcoal kilns must also be adapted for the use with waste materials such as sawdust, shrubs, coffee husks, etc. Associated with the charcoal production are waste gases such as hydrogen, carbon monoxide and methane, which could be used as a fuel source under certain conditions. Similarly there are liquid wastes, namely tar, but the acid contact must be separated before combustion (Pyle, 1978). Some charcoal is used by industry but in future it would seem that the rural population must be accorded first priority.

ENVIRONMENTAL EFFECTS OF PRIMARY SOURCES OF ENERGY

Combustion of Hydrocarbons:

The main products of combustion are carbon dioxide (CO_2) and water vapour (H_2O) but sulphur dioxide (SO_2) is also produced from sulphur in the fuel, as are the oxides of nitrogen (NO_x) from nitrogen in the air. Incomplete combustion results in emissions of carbon monoxide (CO) and hydrocarbons, and in addition there may be particulates including heavy metals. The disposal of waste heat is associated with the combustion process.

CO_2:

The small percentage of CO_2 naturally occuring in the atmosphere has the important function of trapping the infrared radiation which would otherwise escape, thus increasing global temperatures. However the level of CO_2 is now a cause of some concern. Forests, other vegetation, and the oceans are natural sinks for CO_2 but from monitoring over a number of years it appears that the increase of CO_2 in the atmosphere far outstrips the absorption capability of these sinks. Indeed it is speculated that the worldwide indiscriminate burning of trees is now responsible for a large proportion of the increase of atmospheric CO_2. It is estimated that by the year 2000 the average surface temperature of the earth will have increased by 0.5°C to 1.0°C. A 5°C temperature rise is all that is required to melt the polar ice caps.

SO_2:

Sulphur is bound in organic compounds in fossil fuels and difficult to separate. After combustion the SO_2 and some SO_3 is discharged to the atmosphere through tall chimney stacks and carried away by prevailing winds. This is the international practice as techniques for separating the sulphur are beset with technical difficulties. Acid H_2SO_4 (acid rains) may develop on contact with water vapour and these are highly corrosive. SO_2 has deleterious effects on vegetation and also affects the respiratory glands in humans and animals.

NO_x:

These are the oxides of nitrogen, NO and NO_2 and result from high temperature combustion. In sunlight they undergo photochemical processes producing a smog as witnessed in Los Angeles.

CO and Hydrocarbons:

Both are the products of incomplete combustion, and hydrocarbons also reach the atmosphere through evaporation of fuels. CO is toxic to humans, affecting their responses. Hydrocarbons exhibit carcinogenic effects and are an essential ingredient for smog formation, though the process is not fully understood.

Particulates and Heavy Metals:

Particulates, mostly soot, are particles of carbon which can be filtered. The important heavy metal is lead which is poisonous but added to petrol as an anti knocking agent in motor vehicles.

Waste Heat:

Large quantities of waste heat are exhausted to the atmosphere, or to heat sinks such as rivers, lakes and the sea, during most combustion processes. It would seem to have little effect on the atmosphere though may disturb marine life. The higher temperature is likely to increase biological activity in water, but some effects will be positive.

Pollution in Kenya:

At present there are no standards or control on air pollution in Kenya. Standards would be easy to set but more difficult to control. CO_2 reduction will only come about with the reduction of fossil fuel combustion and with less burning of forests. Sulphur emissions may be reduced by importing low sulphur crude oil. However Kenya receives its oil from the Middle East and this is of high sulphur content. After refining the crude oil some fractions have higher sulphur content than others and it may be worth restricting the sale of high sulphur content fuels in urban areas. For the future combustion processes based on fluidised bed technology promise to reduce sulphur emissions. The reason for NO_x causing smog is not fully understood as yet but considerable research is being undertaken in America. Reduction of CO, hydrocarbons and particulates can be achieved by better combustion technology and efficient maintenance. As fuel becomes more expensive the incentive for this will be increased. Provided the same standards of exhaust emissions and combustion techniques as exist in other countries are insisted upon for the cars being imported into Kenya, the air pollution from mobile sources will certainly be no worse than elsewhere. Industrial practice is more difficult to monitor but as a first step some standards on emissions should be set. The disposal of waste heat is likely to become less of a problem in the future due to the economic advantages of recovery systems.

Oil

Oil is imported from the Middle East in tankers of between 50,000 and 70,000 tonnes to the refinery at Mombasa. The Kenya Ports Authority has the equipment to deal with small oil spills (less than 50 tonnes) occuring at sea and which may end up on the beaches, and also accidents in the Harbour of Mombasa. There is provision for a maximum fine of 10000/= plus cost but a greater deterrent is the inconvenience and loss of revenue accruing to a shipping company of having their vessel detained in port until the court case is heard.

Offshore Kenya has recently extended its border to 200 miles. However some 800 to 1000 km offshore is one of the busiest tanker routes in the world. In the event of a major oil spill, perhaps through a collision, which threatened Kenya's coast line and hence the tourist trade, international help would have to be sought. There is an agreement between the 7 major oil companies concerning liability for compensation in the event of a major spill. However this accounts for only 70% of the crude oil transported by tanker.

Small oil spills at sea, usually discharges with bilge water, are also strictly controlled by the major oil companies and their ships are monitored. Again though there are unscrupulous operators who will dump oil if necessary. Whilst slinks of 15 p.p.m. can be detected it is often difficult to place the blame on a particular ship and constant surveillance is an expensive business.

The refinery at Mombasa discharges approximately 2 tonnes of SO_2 daily to the atmosphere, as well as other products of combustion. Fortunately prevailing winds take these out to sea. There is about 0.01% solid hydrocarbon sludge left after refining which is at present buried on site, incineration equipment being too costly. Effluent water from the refinery is treated before being discharged. There have been a number of fires at the refinery recently but these have been extinguished before causing undue damage. The majority of the oil is pumped by the Kenya Pipeline Company to Nairobi where it is stored in tanks. This is an underground pipeline except at the pumping stations which are guarded. The whole process is controlled by computer from Nairobi. There are many shut off valves in the line and continuous monitoring of the oil is carried out. Special precautions have been taken in the design stage to protect the pipeline from corrosion and when ever it comes into contact with rivers and water supplies. The refined petroleum products are further distributed by road and rail and accidents are always a possibility.

Coal

The products of combustion of coal are usually worse than due to oil but the handling and transport which is done by rail is safe.

ELECTRICITY:

Thermal Power Stations

These burn diesel oil or kerosene with the aforementioned effects due to air pollution.

Hydro power

Hydroelectric schemes are not without environmental hazards and this particularly applies to the new upper reservoir scheme which is much bigger than the existing dams and lakes on the Tana River. Families must be moved and resettled elsewhere, bush and tree clearance carried out and potential agricultural land flooded. Once a body of water is formed, water borne diseases are likely to spread. A medical team from the Ministry of Health will monitor this. Wildlife in the area will be affected through loss of grazing land. As it happens there is little in the area of the upper reservoir anyway but what there is is likely to disappear with the exception of hippos. The range of birds will most probably decrease though the number of water birds will increase. The biological activity in the new reservoir will be enhanced initially due to the decay of vegetation and this has consequences for fish breeding. Migratory fish have already been eliminated as no bypass was allowed for on dams lower down the Tana River. The cause of the greatest concern however is the effect of the new reservoir on the flooding of the plains downstream. 50% of all the flood water originates below Kindaruma so that peak floods will still occur. However the flood plain and associated forest and wildlife are included in UNESCO's 'Man and the Biosphere' programme for conservation of rare ecosystems. The plain in addition supports up to 40,000 people who depend on the irrigated crop and seasonal fisheries for their livelihood. The critical period will be when the upper reservoir scheme is completed and the dam being filled when there will be a shortage of water downstream. The filling is estimated to take two flood seasons which have a 70% chance of occuring in one year. However should completion coincide with a spell of dry seasons prospects for the downstream environment are grim. The upper reservoir scheme is the responsibility of the Tana River Development Authority, a statutory body established in 1974 and responsible to the Ministry for

Water Development. They have made provision to irrigate 30,000 hectares in lower Tana and 78,000 hectares in upper Tana. There are problems with irrigation schemes from hydroelectric dams due to salt build up which can only be prevented by proper management. Siltation of dams lower down the Tana river is already a cause of concern and seems to be on the increase due to bad land management upstream causing erosion of top soil into the rivers. The upper reservoir scheme will of course be the catchment for most of this leading to an increase in the turbidity of the water and a shortening of the life of the dam. Hydroelectric schemes have environmental advantages such as no air pollution, mining, processing or transportation of fuel, no waste heat, and dams can become tourist attractions or used for recreational activities.

Wood and Charcoal

The indscriminate consumption of fuel wood has severe consequences on the environment. It leads to deforestation, soil erosion and consequent desertification. The eroded soil ends up in rivers and in the case of the Tana River, collects in hydroelectric dams thereby shortening their useful life. Loss of soil cover also results in faster rainfall water run off in catchment areas, causing reservoir levels and consequent electrical power generation to be seasonal. Once desertification has begun there is a loss of agricutural land potential. Forests are natural sinks of CO_2, the level of which in the atmosphere is increasing. Forest management is essential to eliminate the environmental damage but this may not be compatible with the demand for fuel wood in the rural areas. The combustion of fuel wood and charcoal has other minor effects on health due to smoke and particulates.

OTHER POTENTIAL ENERGY SOURCES IN KENYA AND THEIR ENVIRONMENTAL CONSEQUENCES

Geothermal Energy

This is the most important new source of energy in Kenya for the immediate future. The maximum and minimum potential has been estimated at 1400 MW and 170 MW respectively over a 25 year period for the Ol Karia region alone, where two 15 MW plants are planned for 1981 and 1982. There are a number of environmental worries concerning the development of geothermal energy. Associated with the steam and water underground are the gases H_2S and CO_2 which are emitted to the atmosphere. Sulphur emissions from a geothermal plant are usually higher than from an equivalent fossil fueled plant though estimates at Ol Karia indicate that they will be about the same. H_2S is smelly and toxic to many plants. However air turbulence will disperse the gas and as there is no agriculture within 7 Km of the site there is no immediate cause for concern. As geothermal productivity expands to greater areas this will have to be given further consideration. Some of the CO_2 and H_2S will dissolve in the steam and water forming acids which are corrosive to the turbines. Only steam is passed through the turbines to produce electricity and the associated water is separated. This contains boron, fluorides, and sodium which reacts with chlorine to form sodium chloride. All of them are detrimental to plant life and must be disposed of. Silica is also present and will seal underground flow channels. After the steam has passed through the turbines it is condensed with the aid of cooling towers. The condensate is slightly acidic due to the dissolved H_2S and CO_2 but is a potential source of water for neighbouring farms. The cost of pumping does not warrant such schemes at present, so initially it will be mixed with the separated water and placed in evaporation ponds. The silica is separated out by polymerisation and the remainder either evaporates or infiltrates into the ground. Reinjection into bore holes is a better alternative but the expense is too great in the initial stages of the development. The only restriction placed on E.A.P.L. by the Ministry of Water Development is that the effluent water is not allowed to be discharged into the Naivasha Catchment Area. As geothermal power expands in the 1980's it will become necessary to pump the effluent considerable distances to take it out of the Naivasha catchment area. The geothermal steam is of course associated with seismic activity and, whilst care must be taken in drilling, the activity is of low order at Ol Karia. Blow outs are always possible. Noise is a further hazard but beyond 1 km from the site will have little effect. The advantage of geothermal energy is that it all occurs in one place. Also the E.A.P.L. have shown that the costs of electricity generation by this method compare well with hydroelectric schemes (Table 8).

Small Scale Hydro-power

The consumption of electricity is confined to the urban areas of Kenya due to the expense of connecting isolated rural areas to the national grid. The E.A.P.L. does finance a limited number of uneconomic supplies every year but intensive rural electrification is unlikely in the forseeable future.

TABLE 8: COMPARATIVE PLANT COSTS OF ELECTRICITY GENERATION

	Costs, Cents per kw-hr.
Hydro (based on Gitaru)	16
Geothermal (1976 figures)	18
Steam (based on Kipevu)	30
Gas Turbine	80

Source: E.A.P.L.

The tributaries of the Tana River from Mount Kenya and the Aberdares, and similarly off the Mau Escarpment, offer considerable potential for small scale hydroelectric plants. Theoretically 10 kW plants could be run from a flow of 150 litres/sec over a 10 meter drop. Turbines could be manufactured locally and the civil engineering work is of small scale and could be undertaken by fairly unskilled labour. The T.R.D.A. are currently investigating the viability of a number of potential sites. The schemes are unlikely to be as cheap as other forms of energy but their advantage is that they can provide a means of generating electricity in the rural areas at much less cost than through the national grid system. There are many problems to be faced such as maintenance of the plants, control and distribution of the electricity etc.

Alcohol

Alcohols may be added to petrol and burned in internal combustion engines. A 10% Alcohol, 90% petrol mixture can burn with no modifications to the fuel or combustion system. The advantage of this for Kenya is that Ethanol may be produced from a number of agricultural crops, of which sugar cane seems to have the most potential. Prior to the oil price rise in 1973/1974 it was uneconomic to do so but the situation has now changed. Plans have been laid to build an ethanol factory in Kisumu which should reach full production in 1981 with an output of 20 million litres of ethanol from 100,000 tonnes of molasses. At the ratio of 9 = 1 this is enough ethanol to mix with about half the present motor spirits sold in Kenya. Molasses production is expected to rise to 185,600 tonnes by 1985 and a second ethanol plant is being planned which will then enable all the motor spirit sold to be blended.

Alcohols have a lower calorific value than gasolines due to the presence of oxygen in the molecule but when used in spark ignition engines give a higher thermal efficiency due to higher anti knock quality, and also reduced compression temperatures, which affect NO_x production, due to their high evaporative cooling effect. Thus the power can continue to rise with enrichment and/or speed of the engine. However the risk of fire is greater due to the lower flash points of their vapours. Water solubility is a problem as alcohols easily dissolve water lowering the clorific value and leading to phase separation. Blending is therefore preferably carried out at the point of delivery. Increased molasses production will require land to be set aside but will also help in the elimination of wastes from the sugar factories. It has been suggested that the use of alcohol be intended for rural cooking but the flammability and toxic nature of alcohols make them more suitable for bulk handling by trained personnel. Methanol which has no odour is classed as a poison leading to blindness and death and ethanol is a hypnotic (Goodger, 1977). There are risks for children particularly.

Nuclear Energy

Nuclear energy will form a growing percentage of the developed countries energy consumption in the next century. The expected demand for electricity in Kenya is for 1200 MW (Jabbal, 1978) by the year 2000 and this can be met by hydroelectric, thermal and geothermal means.

Nuclear power plants are capital intensive, though the fuel is cheaper than fossil fuels, and thus built to large capacities of 600 MW and over. The Central Electricity Generating Board of the U.K. estimate that their nuclear power plants now produce the cheapest electricity but the costing of nuclear power is a very debatable question (Sweet, 1978). One of the components not considered in the C.E.G.B. costing is that due to shutting down a reactor as indeed it is not known yet if this is even possible. Energy accounting methods have also shown that the energy involved in mining, transporting, enriching, reprocessing and storing nuclear fuels is greater than the energy output of the plant. However the most contentious issue is that of storing the radioactive waste which is a moral as well as an environmental problem. The potential dangers from nuclear energy are far greater than anything previously experienced by man. To date Kenya has not discovered uranium though a recent airborne survey by C.I.D.A. of the Karro sandstones in the south east of the country is promising. Uranium has been found in similar sandstones in Zambia. A ground survey will follow later this year. Uranium mining is made hazardous by the presence of radioactive radon gas from radium, the 6th stage in the decay of uranium, and proper ventilation is essential. Uranium occurs naturally as U^{238} of which only 0.7% is U^{235} the fissionable material, so that after mining the naturally occuring uranium must be enriched to increase the % of U^{235} to at least 3%. Enrichment plant, either diffusion or centrifuge, consumes enormous quantities of fossil fuels. In the reactor U^{235} is bombarded with slow moving neutrons and the energy released as heat is used to produce steam to drive a turbine for electricity. After fission the uranium must be reprocessed to extract any unused uranium, and also plutonium which is a by-product of the fission reaction. Some plutonium may be utilised in nuclear weapons but the rest must be stored. It is a highly radioactive element which does not exist in nature. One millionth of a gram injected into a dog causes cancer. It also has a half life of approximately 24000 years! Plans at present include fusing it with glass for storage in stable geological formations, or on the bottom of the sea bed, or even firing it into space.

There are other radioactive wastes from the fusion process such as the materials used in the reactor and effluent water discharge from the reprocessing plant. There are also radioactive gaseous emissions, most notably Krypton 85 which has a half life of 10.76 years and is simply exhausted to the atmosphere!

Present commercial reactors are all of the fission uranium type but there are plans to introduce fast breeder reactors which theoretically produce more fissionable material (namely plutonium) than they consume. These are attractive because the supplies of 'cheap' uranium are not expected to last beyond 50 years. There are still many technical problems to be solved but the fast breeder reactor is potentially more dangerous than uranium reactors because it uses fast moving neutrons and no moderator is required in the reactor.

A major worry with the development of fast breeders is that transfers of plutonium around the world will increase, presenting targets for terrorism. The safety record of the nuclear industry has so far been good but if a reactor did burn up, the scale of disaster would have no precedent except perhaps Hiroshima. Also despite assurances by the industry that certain 'things' will not happen, they nevertheless do as witness the latest trouble in Pennsylvania.

<u>Solar Energy</u>

Kenya straddles the equator and as such is in an ideal position to exploit solar energy. This is done to some extent in the drying of agricultural crops and the production of salt at Magadi and Malindi but otherwise there is little activity. The disadvantage of solar energy is that it is intermittent and not available at night. It is also of low intensity such that big collectors of large capital cost are required to achieve high temperatures. Intensification of solar energy is also prone to the energy accounting argument in that systems are likely to need more energy in their manufacture than will ultimately be produced. For these reason the potential for solar energy in Kenya would seem to be suited most to low temperature applications, less than 90°C, and especially water heating and crop drying. Solar water heaters are both imported and made locally with prices ranging from 2000/= to 5000/= per unit. They are easy to make but proper attention should be paid to rendering them less susceptible to corrosion and providing better insulation. There would seem to be considerable potential for such heaters in urban areas initially. A secondary electrical water heating system will still be necessary but estimates show that the capital cost of the solar heater can be recouped in up to 7 years. The demand for hot water in the rural areas is minimal but solar water heaters should be encouraged for use in hospitals, clinics, schools etc. Solar cookers have been made for many years but attempts to introduce them in rural areas, for example India, have always met with failure. The local populations are wary of such devices especially when they do not 'work' on cloudy days. Their advantage is that they operate best in hot dry areas where firewood is most scarce. There is potential for solar water desalination units to provide water in particular areas of Kenya. Solar refrigeration devices are also possible for the storage of food. A limited amount of research is being carried out in Kenya in these fields. A solar water pump is in operation at Wajir but the economics of such devices are unfavourable to their widespread adaption. Radiation data is readily available from the Meteorological Department covering the whole of the country.

Wind Energy

A demand for wind powered water pumps has been identified by UNIDO (Jensen, 1978) and Hilton (1978). There are imported devices available in Kenya but the main emphasis has been on manufacturing local cheaper designs. However these have so far proved unreliable with frequent breakdowns and no trained personnel available to mend them in rural areas. Well designed windmills, as maintenance free as possible and with reliable operation are a much better alternative but these are expensive, of the order of 200,000/= and could only be purchased by villages or cooperatives.

Biogas

Biogas which consists of approximately 60% Methane and 40% CO_2 is produced by the anaerobic fermentation of animal, human and plant wastes. It can be used for water heating, lighting, cooking or as a fuel in internal combustion engines. It is ideally suited to the rural areas.

The Hutchinson Tunnel Co. Ltd., of Fort Ternan have sold a few individual units within Kenya since 1954 but the majority of the population are ignorant of the process. An important factor holding back their development is their capital cost. A steel plant for a 5 cow unit producing 1 m^3 of gas per day is 1650/= (Muthee, 1978). A similarly sized stone plant based on a Chinese design is estimated to cost only 750/= though (Pyle, 1978). Estimates of the potential for biogas in Kenya range from the complete replacement of firewood and with 5840 x 10^{10} kcal available for Mechanisation (Muchiri, 1978) to half the present firewood consumption (Pyle, 1978). Another important factor in biogas plants is the economics governing community or individual plants. Experience in India has indicated that only community sized plants are economic. Pyle (1978) confirms that the larger the unit the better the ecobomics but also shows that if the capital costs can be reduced by introduction of the Chinese stove design, a 5 cow unit becomes feasible. However the costings do not take into account the social implications of community plants. A by-product of biogas-fermentation is the slurry which contains most of the original nitrogen, potassium and phosphates in the animal, human or vegetable waste and is an essential fertiliser for the land. Before introduction into Kenya on a large scale, an analysis of the different designs of unit available, material mixes, problems of the collection of farm waste and disposal of slurry, designs of appropriate gas appliances etc. must be made. A manual of practice for biogas plants would seem to be an essential requirement. Biogas plants are not without environmental consequences, albeit minor, in the handling of dungs and slurries which may promote disease. Small quantities of H_2S are sometimes given off but this is usually an indication that the plant is not working properly. Water availability is also essential.

Solid Wastes

There are large quantities of waste material available in Kenya which could be converted into heat sources for industrial and domestic use, for example coffee husks, sugar bagasse, rice husks, sawdust, maize cobs etc. Unfortunately the equipment to do so is expensive. The Kenya Planters Cooperative Union have a plant which will turn 20,000 tons of coffee husks into 7000 tons of briquettes annually. The plant is self sufficient in energy but the capital cost is £100,000. The briquettes so produced have an equal calorific value to that of charcoal.

CONCLUSIONS

Fuelwood is the most important energy resource in Kenya for the majority of the population and its provision should be accorded first priority. Consumption far exceeds the rate of renewal and every effort should be made to reverse this trend within the limits of competition for land use. In addition forests play an essential environmental role in preventing desertification and soil erosion. Alternative sources of energy particularly solar and biogas are available both for the urban and rural populations of Kenya. However they present a number of technical and financial problems which must be solved before their widespread introduction. Emphasis must be placed on making the country less dependent on imported energy. Alternative sources are important in this respect and also have the advantage of causing less environmental damage.

REFERENCES

Earl, D.E. "Forest Energy and Economic Development", Oxford University Press (1978).

Githinji, P.M., "Kenya's Energy needs, possible supplies and impacts on the Environment", An input to the Government of Kenya/ UNEP/UNDP project on Environment and Development, June(1978).

Goodger, E.M., "Alcohol Fuel Prospects", J. Inst. Fuel, September (1977).

Hilton, D., "Report on Windmill development Project", Dept. of Mechanical Engineering, University of Nairobi (1978).

Jarbal, H., "Planning for Electricity in Kenya in the Midst of Uncertainty", Kenya National Energy Symposium (November 1978).

Jensen, K., "Feasibility of Manufacturing Wind-Powered Water Pumping Equipment", UNIDO Project Findings and Recommendations, January (1978).

Kabagambe, D.M. "Aspects of Resource Conservation". The Role of the charcoal industry in Kenya. Institute for Development Studies Working Paper No. 271, University of Nairobi (1976).

Maitha, J.K. "Energy Balance of Payments Implications", Kenya National Energy Symposium, (November 1978).

Mathenge, J.S. "Financing Energy Development", Kenya National Energy Symposium, (November 1978).

Muchiri, G., "Rural Energy Needs and Alternative Sources", Egerton College Biogas Seminar, (September 1978).

Muthee, A., "The Role of Biogas in the Rural Energy Package., Egerton College Biogas Seminar, September (1978).

Onyango, J.D., "Deforestation and Fuelwood Supply", Kenya National Energy Symposium, (November 1978).

Owayo, C.Y., "Exploration for Energy Minerals in Kenya: Programmes Policies and Implications", Kenya National Energy Symposium, November (1978).

Pyle, D.L., "Energy and Fuel from Biomass", Kenya National Energy Symposium, (November 1978).

Singh, P., "Statistics of Energy and Power", Kenya National Energy Symposium, (November 1978).

Sweet, C., "The Hidden Costs of Nuclear Energy", New Ecologist, No.1, January-February (1978).

PATTERNS OF URBAN HOUSEHOLD ENERGY USE IN DEVELOPING COUNTRIES: THE CASE OF NAIROBI

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SUMMARY

Historically, urbanization has been closely associated with development. The rapid growth and development of urban areas affects national energy demand in several ways. The migration of the rural poor to urban areas involves a shift in the fuel mix toward more commercial fuels, an increase in several energy requirements (e.g. transportation of food from farms to cities). The changing character of the urban populations is also increasing energy demand and altering the fuel mix. In order to evaluate quantitatively the impact of urban growth and development on energy use, a structured analysis of their interdependencies is required.

In this study, the energy consumed to support the activities of Nairobi households is evaluated at five income levels. The activities considered are transportation, food consumption, housing (construction), direct residential uses and services. Household transportation and residential energy uses, where energy is consumed directly by the activities, are assessed in terms of the activity levels, the fuel mix and the relative effectiveness with which the energy demands are satisfied by the different fuel/technology combinations. In the remaining sectors, (housing, services, and food) the energy used in producing and distributing the food or service is estimated on the basis of assumptions about the processes employed and fuel purchasing data.

The resulting energy use profiles are analyzed with an emphasis on the policy implications and their potential use in energy conservation assessments and demand projections. Income related changes in the magnitude and fuel mix of the energy requirements are evaluated and potential high growth areas are identified. Several key areas amenable to government policy are discussed with particular reference to the situation of low income households. Finally, suggestions are made on how the profiles could be refined and extended.

INTRODUCTION

Historically, urbanization has been closely associated with development. U.N. population projections show the urban areas of the LDCs growing from 27 percent of their total population in 1975 to 41 percent by the year 2000. Simultaneously, there is a tendency for the urban areas to become larger and more concentrated. Kenya is no exception to this rule. Estimates at 11.31 percent in 1975, the urban population proportion is projected to grow to over 20 percent by 2000.

This rapid growth and development of urban areas in many LDCs is affecting their energy demands in several ways. Low income migrants who previously used wood and charcoal generally purchased more oil based fuels when they move to the cities. In addition, the urban populations have energy requirements which do not exist in the traditional rural areas. Food and raw materials, for example, must be transported to the cities. A sophisticated energy consuming distribution system is required within the larger urban centers and perishable products must be preserved and packaged. New, more energy intensive products become available for consumption.

The changing character of the urban population itself increases energy demand and alters the fuel mix. The growth in per capita income, in particular, causes higher levels of expenditure on energy intensive goods and services. In addition there appears to be a trend toward more sophisticated energy amenities (e.g., electric applicances) at all income levels.

The urban areas thereby represent an important link between development and energy use. In order to understand more fully the relation between urban growth (and development) and energy use, a structured analysis of their interdependencies is required. The issue is not how energy is used in urban areas themselves, but rather how energy is used globally to support the activities of the urban population. Thus the traditional end-use sector analysis focusing directly on energy consumers is inadequate, and a different perspective is required.

The approach followed in this study is to analyze direct and indirect energy demand as it relates to various urban household activities at different income levels. This represents the second application of such an approach to a major urban area in an LDC. The approach used in the first study, "Patterns of Urban Household Energy Use in Developing Countries: the Case of Mexico City", (McGranahan and Taylor, 1977) has been modified to allow for differences in data availability. This methodology is intended to:

1. Illustrate the relationship between urban household activities and the use of energy resources. In particular to give quantitative estimates to the energy use currently associated with the various household activities (e.g. amount of gasoline used in personal transportation, fuels used to provide a family with food, etc.).

2. Assess government policies in terms of their impact on energy resource consumption. For example, to estimate the energy that could be saved through housing policies locating residences near the workplace, introducing an electric mass transportation system or promoting the introduction of more efficient cooking devices.

3. Evaluate the potential impact of energy shortages on household activities in different income groups. In particular, to identify those activities which are heavily energy dependent and to assess the flexibility both of the activity levels and their associated energy requirements.

4. <u>Project future energy demands associated with urban household activities.</u> Scenarios of future energy demand can be developed on the basis of alternative assumptions on future population, income level (and distribution) and energy efficiencies.

In addition to an analysis of the energy use patterns as they apply to Nairobi in particular, we have undertaken a comparison of the situations in Nairobi and Mexico City. Although with only two cities it is virtually impossible to separate out those differences brought about by the larger size of Mexico City from those inherent in the cultural and socioeconomic characteristics, the comparison provides the basis for a consistency check of our initial assumptions regarding the relationship between energy use and level of urbanization.

APPROACH

Method of Analysis

In this study, urban energy demand is analyzed through its relationship with household activities. As such, energy use is categorized according to its function in supporting the household unit.

The approach centers on the construction of energy use profiles for different income groups. The household income intervals, in 1970 Kenya Pounds per annum, are: Group one - 0 to 204; Group two - 205 to 600; Group three - 601 to 1200; Group four - 1201 to 3600; Group five - over 3600. Household activities at each income level are treated separately and broken down into subgroups when necessary. The activities considered are:

- Transportation
- Direct Residential Energy Use
- Food Consumption
- Housing (construction)
- Services.

For transportation and residential uses, where the energy is consumed directly by the activities, the analysis includes both the activity levels and the relative effectiveness with which the associated energy demands are satisfied. For example, in the transportation sector, estimates are made of the average number of passenger kilometers travelled by foot, car, matatu, and bus for each type of household. Total passenger kilometers per household is thereby used as a measure of the activity, transportation. Fuel consumption is also calculated by mode. In this way, changes in distance travelled, vehicular efficiencies and the mode splits can all be analyzed. A similar procedure is followed for the residential sector.

In the food, service and housing sectors, the energy is consumed before the goods and services are supplied and the situation is more complex. The activities only indirectly reflect the details of the energy inputs. For these sectors the energy embodied in the goods or service is estimated. Embodied energy is defined as the total primary energy* used in producing and distributing the goods or service. The embodied energy in food, for example, is the energy content of the fuels used on the farm, in the transportation, and in all processing and packaging of the food before it is purchased by the household. As such it is inappropriate to talk in terms of a physical efficiency of energy use in supporting these activities. It is, rather, the feasible range of energy requirements which is important.

In all sectors the energy requirements are expressed in terms of primary energy inputs. Five fuel forms are considered: oil based, electricity, charcoal, wood and metabolic. For most energy uses, the energy content of the fuel (see appendix B) is used as an approximation of primary energy. Electricity figures are converted into primary energy assuming a conversion efficiency of 30%.

Direct country specific information necessary to carry out the energy analysis is not always available in an explicit form. It must be constructed from a variety of data that represent the conditions in the country. For the most part activity levels are derived from information used in urban planning. The Nairobi Urban Study Group, for example, had collected information on transportation patterns and housing requirements at several income levels. Food consumption patterns although not often used in planning, are implicit in the compilation of cost of living indices for different income groups. Only information on the direct residential fuel using activities is required predominantly for energy studies.

The principle areas for which no adequate information on activity levels is available from official sources are the direct residential energy uses, particularly at lower income levels, and the services sector. To overcome this difficulty, in the residential sector, a small household survey was carried out, concentrating on low income households, along with a sampling of electricity sales in several areas. The analysis of the services sector is by necessity still in a preliminary form.

To assess the energy requirements associated with the activities various procedures are used including the use of fuel consumption data, process analysis, and the application of generic energy coefficients. These procedures are best illustrated with reference to the individual sectors.

Limitations:

The reliability of the results is limited by the lack of field data on the energy inputs to the production of several goods and services in Kenya. In several areas the absence of such information has forced us to make assumptions about the types of processes employed. Although the resulting energy estimates are not unreasonable, there remains a considerable degree of uncertainty. This is particularly

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* Primary energy is defined as the enery inputs before any conversions take place. As such it is a measure of resource depletion when applied to non-renewable fuels.

true for highly processed foods and construction materials for which energy coefficients from developed countries were applied with only minor adjustments. Even in those areas for which adequate fuel or process information was available, the time period over which the data have been gathered puts some restrictions on their comparability. The small sample size (150 comprehensive, 212 electric) of the household survey is another source of error. Together these data weaknesses limit the accuracy of the results and care must be taken not to overstep their reliability in the search for conclusions.

The measurement of income also provides problems. Ideally the income groups should be defined in terms of permanent real income since activity decisions are not based on current income alone. To estimate permanent real income would entail a knowledge of expected future monetary incomes as well as income in kind and tax payments. Since a large section of our activity level information is based on secondary data sources and since detailed information is required to estimate permanent real income, we have restricted our analysis to income in the current period as defined by the Kenya Central Bureau of Statistics and assume that alternative secondary sources have done the same.

Three limiting aspects of the methodology itself are worth mentioning. Firstly, since not all energy is used to support household activities, and since it is not feasible to consider all indirect energy requirements, there remains a portion of energy use unaccounted for. This approach is meant to compliment other forms of energy demand analysis and should not be expected to represent the energy system as a whole.

Secondly, implicit in the use of the energy use profiles as a basis for projections, is the assumption that as a household increases in income its activity levels alter to confirm with those of the higher income groups. In certain cases this will not hold true. One would not expect, for example, that a poor African family whose income is increasing will start eating more curried rice, as is characteristic of the current, more Asian, middle class.

Finally, the energy profiles specify the average rather than the marginal energy values associated with the activities. As such, in examining the future energy requirements of increasing activity levels it is important to evaluate any possible divergence between the average and marginal values. This would be particularly important in the food sector where increasing productivity under severe land constraints could entail more energy intensive farming techniques.

RESIDENTIAL

Procedure

The direct use of energy in the home is broken down into six sub-activities: cooking, water heating, lighting, space conditioning (air cooling and heating), major appliances and minor appliances. Income group average activity levels are defined in terms of their basic energy demand.

Basic energy demand refers to the energy consumption necessary to support an activity level in a situation of 100% technological efficiency. As such, the basic energy demand for sustaining a given activity is independent of the fuel-technology combination. The basic energy demand of an activity is defined most appropriately by the equation relating it to the efficiency of the technology and the energy present in the fuel used in performing the activity.

When a given household performs a specific activity (labelled i) using n fuel-technology combinations (labelled j, where j goes from 1 to n), the basic energy demand of the activity B_i is related to the energy present in the fuels, F_{ij}, consumed in the activity by the equation:

$$B_i = \sum_{j=i}^{n} e_{ij} F_{ij}$$

The proportionality constant, e_{ij}, is the technological efficiency of the device used in performing the activity. The efficiency carries two indices because a given device can be used in the fulfillment of more than one activity or with more than one fuel, for accomplishing a single activity. For example, a household might use charcoal in a jiko for cooking and for preparing hot water.

The profiles of consumption by direct use (Tables 1-5) give a tabulation of the basic demand per household for each activity at each income level under the column labelled "B". The tabulation is broken into components when the households at a given level of income use different fuels and technologies of different efficiencies for accomplishing the activity. Each component equals the portion of the given activity level which is satisfied by the fuel-technology combination specified. Thus, the column "B", lists an estimate of the basic demand for the activity (which should be nearly the same for all households from a given income group) and, when more than one technology-fuel combination is used in the group to support the basic demand, an average group component of the basic demands from the technology-fuel combinations employed.

A similar tabulation of the quantities of energy present in the fuels consumed in each activity is listed under the column labelled F. We will refer to the energy in the fuel consumed in performing the activity as the fuel specific demand of the activity.

This framework provides a representative picture of the essential features of energy consumption for each income group and allows for analysis of changes in both amenity levels and technologies. To build the profiles, in addition to overall fuel consumption figures, two of the following three group dependent quantities are required for each activity at each income level:

1. The average percentage of a given fuel used by a household to perform the activity over a period of time.
2. The efficiency attached to each fuel/technology combination used in the fulfillment of the activity.
3. The per household basic demand associated with the activity over a period of time.

Given estimates of all three variables, the redundancy supplied by the equation relating fuel specific to basic demands can be used to verify the consistency of the data.

The principle sources providing estimates for these variable were the responses to a home survey of one hundred and fifty households[2] and

Table 1. Residential energy use Profile.

Household Income: 0–204 K£ (1970)/annum

End Use	Technology	Fuel	Unit/month	Conversion ($J \times 10^9$/Unit)	F: (10^9J/annum)	e:	B: (10^9J/annum)
Cooking +	Hearth	wood	.171 cu.ft.	.148	.30	.1	.03
Water heating	Jiko	charcoal	1.72 sacks	.611	12.6	.2	2.50
	Paraffin stove	paraffin	2.00 gallons	.172	4.13	.4	1.65
				Sub total	17.0		4.18
Lighting	Hurricane lamp	paraffin	1.12 gallons	.172	2.31	.1	.231
				Total	19.3		4.41
				Fuel breakdown			
				wood	.30		.03
				charcoal	12.6		2.50
				paraffin	6.44		1.88

F = Fuel specific energy demand

e = Efficiency

B = Basic energy demand

Note: Fi for electricity if defined as primary energy inputs assuming 31% efficiency of conversion to electric energy.

Table 2. Residential Energy Use Profile.

Household Income 205-600 K£ (1970)/annum

End Use	Technology	Fuel	Units/month	Conversion ($J \times 10^7$/unit)	F: (10^9 J/annum)	e:	B: (10^9 J/annum)
Cooking +	Jiko	charcoal	1.7 sacks	.611	12.5	.2	2.5
Water heating	Paraffin stove	paraffin	1.19 gallons	.172	2.46	.4	.98
	Gas stove	liquid gas		.046	1.58	.7	1.1
				Sub total	16.5		4.58
Lighting	Hurricane lamp	paraffin	.274 gallons	.172	.57	.1	.06
	Indcandescent bulbs	electricity	12.2 kwh	.0116	1.7	.3	.512
			Sub Total		2.27		.57
			Total		18.8		5.2
				Fuel breakdown			
				Charcoal	12.5		2.5
				Paraffin	3.03		1.0
				Liquid gas	1.6		1.1
				Electricity	1.7		.51

Table 3. Residential Energy Use Profile.

Household Income: 601-1200 K£ (1970/annum)

End Use	Technology	Fuel	Units/month	Conversion ($J \times 10^9$/Unit)	F: (10^9J/annum)	e:	B: (10^9J/annum)
Cooking	Jiko	charcoal	.60	.611	4.40	.2	.88
	Paraffin stove	paraffin	.62	.172	1.28	.4	.51
	Gas stove	liquid gas	14.7	.046	4.64	.7	3.25
	Electric stove	electricity	18	.0116	2.51	.31	.78
				Cooking - Total	12.8		5.42
Water heating	Jiko	charcoal	.62	.611	4.55	.2	.91
	Paraffin stove	paraffin	.64	.172	1.32	.4	.53
	Gas stove	liquid gas	8.7	.096	4.83	.7	3.38
	Electric heater	electricity	45.9	.0116	6.39	.31	1.98
				Water heating-total	17.9		6.80
Major applicances	refrigerator, washer, etc.	electricity	54.9	.0116	7.64	.31	2.37
Minor appliances	radio, TV, etc.	electricity	40.0	.0116	5.57	.31	1.73
Lighting	incandescent bulbs	electricity	18.5	.0116	2.50	.31	.78
Space condition-ing	fans	electricity	.71	.0116	.10	.31	.03
				TOTAL	46.5		17.1
				Fuel breakdown			
				charcoal	8.95		1.8
				paraffin	2.60		1.0
				liquid gas	9.5		6.6
				electricity	24.7		7.7

Table 4. Residential Energy Use Profile.

Household Income: 1201-3600 K£ (1970/annum)

End Use	Technology	Fuel	Units/month	Conversion (10^9J/unit)	F: (10^9J/annum)	e:	B: (10^9J/annum)
Cooking	Jiko	charcoal	.96 sacks	.611	7.04	.2	1.41
	Gas stove	liquid gas	16 kilos	.046	8.83	.7	6.20
	Electric stove	electricity	28 kwh	.0116	3.90	.31	1.21
				Cooking total	19.8		8.82
Water heating	electrict heaters	electricity	201 kwh	.0116	28.0	.31	8.67
Major appliances	refrigerator, etc	electricity	95 kwh	.0116	13.2	.31	4.10
Minor appliances	radios, etc	electricity	42 kwh	.0116	5.85	.31	1.81
Lighting	incandescent bulbs	electricity	32.6 kwh	.0116	4.54	.31	1.41
Space condition-ing	fans	electricity	1.5 kwh	.0116	.21	.31	.06
				TOTAL	71.6		24.9
				Fuel breakdown			
				charcoal	7.04		1.4
				Liquid gas	8.8		6.2
				electricity	55.7		17.3

Table 5. Residential Energy Use Profile.

Household Income: 3600+ K£ (1970)/annum

End Use	Technology	Fuel	Units/month	Conversion (10^9J/unit)	F: (10^9J/annum)	e:	B: (10^9J/annum)
Cooking	Jiko	charcoal	.67 sacks	.611	4.9	.2	1.0
	Gas stove	liquid gas	2.1 kg.	.046	1.16	.7	.46
	electric stove	electricity	180 kwh	.0116	25.0	.31	7.75
				Cooking total	31.0		9.2
Water heating	electric heaters	electricity	230	.0116	32.0	.31	9.9
Major appliances	refrigerator etc	electricity	144	.0116	20.0	.31	6.2
Minor appliances	radio, etc	electricity	51	.0116	7.1	.31	2.2
Lighting	incandescent bulbs	electricity	98	.0116	13.6	.31	4.2
Space conditioning	fans	electricity	5		.70	.31	.2
				TOTAL	104.0		32.0
				Fuel breakdown			
				charcoal	4.9		1.0
				liquid gas	.7		.46
				electricity	98.4		30.5

electricity billing information supplied by East African Power and Lighting.[3]

In practice, of course, households could not supply values for the efficiencies of the technologies they employed. Also, though households usually can supply fuel-energy indicators (fuel bills, estimates of expenditure for fuel per month, estimates of sacks of charcoal consumed per month, etc.) from which one can derive a profile of fuel consumption for all activities combined, most households do not have a feeling for the break-down by activity of their consumption. Further complicating the construction of income group activity profiles for Nairobi is the use of more than one fuel for an activity, the use of one fuel for more than one activity, and the wide variation of the fuel-energy equivalences of wood and charcoal.

To overcome these problems and to obtain values in those cases where no direct information was available, a series of ad hoc procedures was adopted. These procedures make use of the equation noted above along with efficiency estimates established elsewhere and scaling factors for basic demand linked to observable amenities. The following sections illustrate the m ethod used for each sub-activity.

Lighting

The household survey provides information about wattages per household connected for lighting in each income group. This information along with household size and room number is used as a lighting amenity level indicator[4]. A unit basic demand scale is derived relating the basic demands of group 5 (the highest income group) to groups four and three by assuming that among the three groups, households require lighting for the same number of hours each day. Since lighting requirements also should depend on household size and the number of rooms present, the unit basic demand scale is derived on the assumption that the lighting consumption per person per room divided by total wattage is an income invariant[5] quantity when applied to groups five, four and three. Since we assume electrical appliances have an efficiency of unity, the amenity indicator assumption is tantamount to equating the hours of lighting per person per room required by groups 5, 4 and 3. Since the essential lighting requirement is fulfilled in these groups, the assumption is reasonably sound. However, at the outset, whether or not the assumption applies to group 2 households is questionable since the number of hours of lighting required by members of the group might not meet minimally acceptable standards.

On the other hand, the survey indicates the bulk of group 2 electricity consumption results from the use of electric lights (insignificantly small numbers of other electrical devices are present in group 2 households). Consequently, to a good approximation, the electricity bill from a group 2 family should reflect direct use of electricity for lighting only. The plausibility of this last assumption is confirmed by a calculation of the number of hours of lighting per day (four) required by a household whose basic lighting demand equals the total electricity demand given for group two households by the billing information and which uses 100% of the estimate provided by the survey of the average total wattage available for lighting (175) in group 2 electricity consuming households. Hence, the implication is that the billing information provides a suitable estimate for the group's basic lighting demand.

To calibrate the scale relating the basic demands of the three highest groups, it was assumed that households from the highest group and families from the United States illuminate their homes at comparable levels[6].

We tested the plausibility of the estimates which resulted from the scaling and calibration procedure in two ways:

1. Given a reasonable estimate of the number of hours of lighting required each day by all groups (four hours), we found that the scaling-calibration procedure can be applied to derive a value for the group 2 basic lighting demand per household which agrees with the estimate of basic demand obtained from the billing information.

2. A reasonable value for the percentage of light bulbs lit continuously four hours each day of the total number of bulbs present in the household was derived for each group from the basic demand generated by the scaling-calibration procedure and from the wattage available for lighting and wattage per light bulb information supplied by the survey.

The results of the two plausibility tests and estimates of basic lighting demands for groups 2-5 are summarized in Table 6.

Given the value for the group 2 basic lighting demand from the electricity consumer information and knowing the rate of paraffin consumption for lighting required by group 2 paraffin consuming households, we derived the relative effectiveness of the paraffin lamp. This procedure enables us to extract the fuel specific demand for paraffin associated with group 2 lighting. To extract the basic lighting demand for the first group, we multiplied the basic demand of the second group by the ratio of the number of person-rooms present in group 1 households to the corresponding group 2 value. (The estimate is consistent with assuming that lighting per person-room in groups 1 and 2 remains the same, disregards the possibility of more paraffin lamps in group 2 than group 1 households; the survey reveals that group 2 and group 1 paraffin consumers have only slightly different numbers of lamps.)

Cooking:

An estimate of the fourth group's basic cooking demand comes from information supplied by East African Power and Lighting and from various interviews with other group 4 households. For the three highest groups, the total number of food cooked[8] per year per household served as the parameter from which a basic demand scale was derived; the extrapolation of estimates for the third (fifth) group's basic cooking demand consisted of scaling group 4 basic cooking demand by the ratio of the number of kilograms of food cooked by the third (fifth) to the corresponding fourth group value per household per year.

Table 6. Lighting Information.

	Wattage/ H.H.	Person-Rooms	Watts/ bulbs	KWH**/RM-Pers*	KWH**/ mo
Group 2*	75	7.44	47.5	—	14.4
Group 3	281	24.4	70.2	8.79	17.9
Group 3	519	24.09	53	16.25	32.6
Group 5	1303	28.8	66.3	40.8	97.9

* For groups 3-5, all lighting is done by electricity; for group 2, 63.7 percent of the households interviewed use electricity for lighting; the quoted values correspond to the lighting requirements of group 2 electricity consumers only.

** KWH in KWH/RM-Pers-yr and in KWH/mo refers to the secondary value (the amount present in the household, not the amount present in the fuels used to generate the electricity required for lighting) of the electrical energy.

For the first and second groups, the direct use demand values associated with cooking are included with those corresponding to hot-water preparation. The fuel specific demands for the conglomerate, hot-water preparation-cooking, were derived by subtracting the fuels required for lighting from the remaining fuel totals. Basic demands for hot water preparation-cooking were derived from the fuel specific demands using the assumed cooking device efficiencies listed in Table 1. Applying the amenity level indicator, kilograms cooked per year, as a parameter to gauge the basic cooking demand scale is a crude approximation at best; again, the gross distinctions between the life-styles of the fourth and second groups further preclude our attempting to apply a basic demand scale calibrated by observations of the second highest income group to derive basic demands for any group whose income is lower than the next highest group (group 3).

Space conditioning

Space conditioning appears to be a minor component of energy consumption throughout Nairobi; air conditioning was not present in any of our survey households. We used the relative the numbers of fans present in groups 2, 3, 4 and 5 to set a basic demand scale for the activity. A small but 'reasonable' value for fan use (one hour per week) was assigned to group 5 residents. Then the scale set the value of the space conditioning component for the remaining groups.

Hot Water Preparation (h.w. prep)

The direct use associated with h.w. prep. for groups 1 and 2 is included in that associated with the conglomerate, h.w. prep.-cooking.

Our estimates of basic and fuel specific demands for hot water preparation in groups 4 and 5 come directly from East African Power and Lighting billing information. East African Power and Lighting has divided household electricity billing between two tariffs, one reserved for electric water heating (tariff 6), one for all other electrical demands (tariff 1). Since the household survey information indicates that one hundred percent of all group 4 and 5 households use electricity for water heating, we were able to correlate the water heating billing information for the two upper groups. Furthermore, the survey tells us the electrical consumption for each group, and we were able to extract h.w. prep. requirements (the unit basic demands) for the two upper groups.

Extracting h.w. prep. demands for group 3 households posed various problems. Less than twenty percent of group 3 households use electric water heaters for heating water. The survey indicates that households heat water for hygenic purposes by gas and charcoal. Especially in the higher income households of the group (Kariokor), water heating levels appear high; but they decline substantially among the lower income households (Umoja).

To extract the group 3 h.w. prep. basic demand, we assumed the activity accounts for all fuel demands for gas and charcoal not included in fuel specific totals for cooking for group 3. We calculated the group's fuel specific cooking demands from the basic demand (we derived the basic cooking demand by scaling group 4 demand by the ratio of kilograms of food cooked in group 3 to the amount cooked in group 4) weighted according to the percentages of households using gas and charcoal. We further assumed that households owning electric water heaters require hot water at the level common to group 4 and consequently scaled the group 4 electrical water heating demand by the ratio of the average number of water heaters in group 3 households to the number in group 4 households. Working backwards from the group's fuel specific demands for water heating by charcoal and gas, we derived an average water heating unit basic demand for households which heat water using their cooking devices. Adding this unit basic demand to the average electrical demand (household appliances have unit efficiency), we generated an estimate of the group's unit basic demand for h.w. prep.

The procedure for extracting group 3 basic demand for h.w. prep. and much of the analysis of lighting probably are more elaborate than the accuracy of our data warrants. However, the resulting hot water and lighting profiles are not unreasonable, and the procedure demonstrates the utility of the basic demand concept; i.e., knowing the basic unit and fuel specific cooking demands for example, we were able to derive the corresponding h.w. prep. demands.

Major and Minor appliances

The remaining electrical demands (after h.w. prep., cooking and lighting have been extracted) were distributed between major and minor utilities on a scale based on the numbers of appliances of each type— i.e., based on the available wattage of each appliance type - present on the average in each household group. As a plausibility check against gross errors in the resulting estimates, the unit levels for each appliance type (watt-hours/day of usage of major or minor appliances) were calculated and contrasted with comparable unit level information appropriate to the United States.[11]

Discussion:

Because our data base is limited, the interface between inferred speculations and verifiable conclusions cannot be sharp. However, certain trends appear to obvious they should be mentioned.

In all income groups, the combined direct uses associated with water-heating and cooking account for more than 50% of all basic and fuel basic demands. Indeed, in all groups except the highest, the data imply that the combination accounts for at least 70% of all basic demand associated with direct usage and gives a comparable lower bound on the percentage of total fuel specific demand. In the lowest two groups, the sector accounts for roughly 90% of all fuel specific and basic demands (Tables 1-2).

In Mexico City and in the United States, the two activities are also the most significant avenues of consumption but are responsible for slightly lower values of the percentages (10-15 percent lower) of the total fuel specific and basic demands associated with residential direct usage for all groups.

The direct uses associated with lighting account for between five and ten percent of total direct fuel specific and basic demands for the four lowest groups. This value is slightly lower than the corresponding value for the highest group and for the United States and Mexico City (12-15 percent).[10]

As one would expect, with increasing income, household amenities increase. More significantly, the efficiency of usage also changes. The lowest groups cook primarily with the Jiko and paraffin stove. The efficiencies of these two devices have not been measured precisely, but the Jiko (the predominant cooking technology) appears to have an effectiveness intermediate between the hearth (the efficiency of the hearth is roughly .1) and paraffin stove (paraffin stove carries an efficiency of roughly .3-.4). In the third group, a visible substitution of gas stoves (efficiency of .7) for the jiko and paraffin stove appears, while in the fourth group, the substitution of electricity for all other energy forms begins to occur (75% of all energy entering households from the fourth group is in the form of electricity, and in the highest group, the switch from primary fuels to electricity is virtually complete).

TRANSPORTATION

Procedure

The Metropolitan Growth Study[11] (1970) provides the data base for our estimates of the transportation component of household energy consumption. Consequently, our estimates neglect travel by households to points outside the city limits since the Growth Study only provides information about trips which commence and terminate within Nairobi. The analysis makes projections of consumption arising from the use of four modes of transportation, privately-owned cars, matatus[12] public transport (the local bus company), and walking-bicycling.

Our procedure for estimating the transportation component of household consumption involves two steps:

1. estimating the mileage a household from each group travels during a year by each of the four modes,
2. the extrapolation of a reasonable values for the fuel-energy consumed for each passenger-mile of travel by each mode from U.S. transportation information.[13]

As in the Mexico City study,[14] we generate estimates of yearly mileage by mode for each group from values for the mode and group dependent quantities; trip frequency and length.

We derive the trip frequency for each mode and group from the study's listing of daily household trip rate by income (Tables 4.1, 4.2 of the Growth Study[15]; the listing gives the number of daily trips made by all household members of all modes) and its distribution by income of the percentage of household trips by different modes (tables 4.7-4.8, Figures, 4.7, 4.8).[16]

Since matatu travel was illegal in 1970 and since the study provides no direct information about the percentage of trips made by the mode, our procedure for extracting the corresponding trip frequency is not self-evident. We inferred an appropriate value from the author's observation[16] that a large percentage of the small but not wholly insignificant number of trips made in privately-owned automobiles by non-car owning households were by matatu. Since the energy component associated with car trips by non-car coming households in privately-owned automobiles other than matatus is an even smaller quantity, and since matatu travel has increased markedly since 1970; we have decided to approximate all travel by non-car owning households in privately-owned automobiles as travel by matatu, to neglect car trips by such households in automobiles other than matatus. The resulting estimates do not alter significantly the value of the component corresponding to travel by all households from a group in privately-owned automobiles other than the "illegal" taxis, and assign a more appropriate loading factor to the percentage of car trips made by non-car owning households in matatus than the one corresponding to the common loading habits practised by most owners of cars (most matatus are greatly over-loaded, carry an average loading efficiency two to three times the value appropriate to travel in most privately-owned automobiles).

We calculate the average trip lengths by each mode from the study's trip length probability distribution (section 4.4)[17]. We use the same trip length for a given mode for all groups and the automobile trip length for the matatu. The average lengths per trip and daily mileage (product of trip length and frequency per day) by each mode are tabulated for all groups in Table 7.

The fuel efficiency for privately-owned automobiles corresponds to that of an urban sub-compact (24 miles/U.S. gallon)[18], the factor for the matatu correspnds to that of a 15 passenger minibus filled to 75 percent capacity[20], or, equivalent to a 50 passenger diesel bus (4-5 miles/u.S. gallon)[7] filled to eighty percent of capacity. To a good approximation, the loading factor for public transport (diesel bus) should be very nearly equal to that of the matatu. In a more complete study, the loading factors for all three modes (bus, matatu, automobile) would be calibrated more precisely. The conversion of food-energy to travel by walking-cycling was assumed to be 50 kcal (2 1×10^5J)mile. Table 7 summarizes the results of the analysis.

Table 7. Yearly Fuel-Energy Consumption and Mileage by Mode.

Public Transport

	Mileage trip	Mileage day	Mileage year	Conversion	Fuel	Fuel-Energy (10^9J)
Group 1	2.75	.39	142	10^6J/mile	diesel	.14
Group 2	"	1.85	675	" seat	"	.68
Group 3	"	3.94	1,438	"	"	1.4
Group 4	"	1.72	628	"	"	.63
Group 5	"	1.09	393	"	"	.40

Privately-Owned automobile

Group 1	2.44	.2	55	$5x10^6$J/veh mile	gasoline	.3
Group 2	"	.9	330	"	"	1.7
Group 3	"	7.1	2,610	"	"	13.0
Group 4	"	21.1	7,710	"	"	39
Group 5	"	31.4	11,440	"	"	57

Matatus

Group 1	2.44	.51	184	10^6J/mile	gasoline	.18
Group 2	"	1.23	449	"	"	.45
Group 3	"	1.10	401	"	"	.40
Group 4	"	.78	284	"	"	.28
Group 5	"	.74	270	"	"	.27

Foot-cycling

Group 1	1.44	3.57	1,300	$2.09x10^6$j/m		.27
Group 2	"	6.30	2,300	"		.48
Group 3	"	5.61	2,050	"		.43
Group 4	"	2.84	1,040	"		.22
Group 5	"	1.65	600	"		.13

Table 8. Yearly Mileage by Mode.

	Total Mileage	Mileage/ ft.cyc	Mileage/ matatu	Mileage/ bus	Mileage/ Car
Group 1	1,680	1,300	180	140	60
Group 2	3,760	2,300	450	680	330
Group 3	6,500	2,050	400	1,440	2,610
Group 4	9,670	1,040	290	630	7,710
Group 5	12,710	600	270	400	11,440

Table 9. Yearly Fuel-Energy Consumption by Mode.
(10^9 Joules)

	Total Fuel Energy	F-E/ft-cyc	F-E/Matatu	F-E/Bus	F-E/Car
Group 1	.9	.27	.18	.14	.3
Group 2	3.3	.48	.45	.68	1.7
Group 3	15.3	.43	.40	1.44	13.0
Group 4	39.7	.22	.28	.63	38.6
Group 5	60.0	.13	.27	.40	57.2

Discussion

The transportation energy use profiles are summarized in Figure 1 and 2. Especially among the lower income households, travel in Nairobi occurs primarily by foot or bicycles. These modes account for almost 80% of the total mileage travelled per household in the lowest group, 65% in the second lowest group, decline to 30% for the middle group and to less than 10% for the two highest groups.

The decrease with rising income of travel by metabolically powered transportation modes is more than balanced by sharp increases in the use of automobiles. The shares of total travel-mileage by automobiles are 3, 9, 40, 80 and 90 percent for groups 1-5 respectively. The rapid rise in automobile usage with income is associated with increasing household mobility since the average car trip is almost twice the average foot-cycling trip length (the high income households also tend to make more trips).

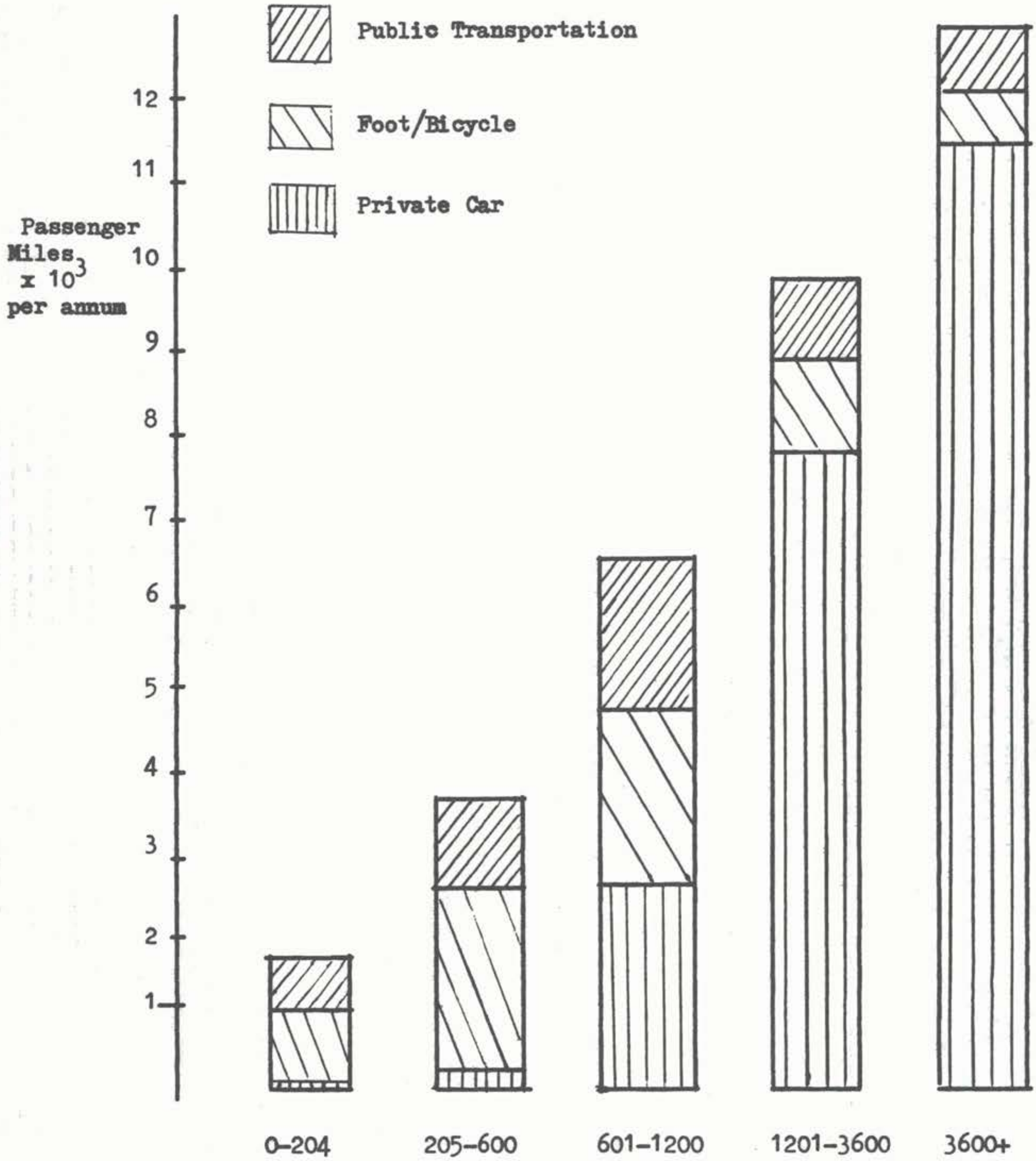
The percentage shares of public transport and matatu mileage of total mileage remain relatively constant with income. The matatu accounts for 11, 12, 6, 3 and 2 percent of the total mileages travelled by groups 1 through 5 respectively; while the corresponding group values of the percentage share of total mileage by bus are 9, 18, 22, 7 and 4.

Thus, in thetwo lowest groups, travel is predominantly by metabolically power modes; in the two highest, travel occurs primarily in the automobile. In the middle group, the two modes, automobile and foot-cycling, account for nearly equal shares of total travel distance, and their combined total is responsible for 70% of all travel-miles. The combination of these mode shifts and the eight fold increase in miles travelled over the income range, leads to the dramatic, 60 fold, increases in energy consumption illustrated in Fig. 2.

Our analysis shows household consumption from transportation at a much lower level in Nairobi than in Mexico City for all income groups. The disparity appears to reflect differences in city-size, degree of urban sprawl, level of urban congestion, and the resulting differences in travel patterns. Average trip lengths in Nairobi range between 1.5 to 2.8 miles. The comparable limits in Mexico City are roughly 3.5 and 6.0 miles. The travel time for the average automobile trip in Mexico City (trip length of 6 miles) is greater than 20 minutes. The average time required to make an automobile trip of comparable length in Nairobi is not known by the authors. However, one suspects its value is well below the Mexico City transit-time figure.

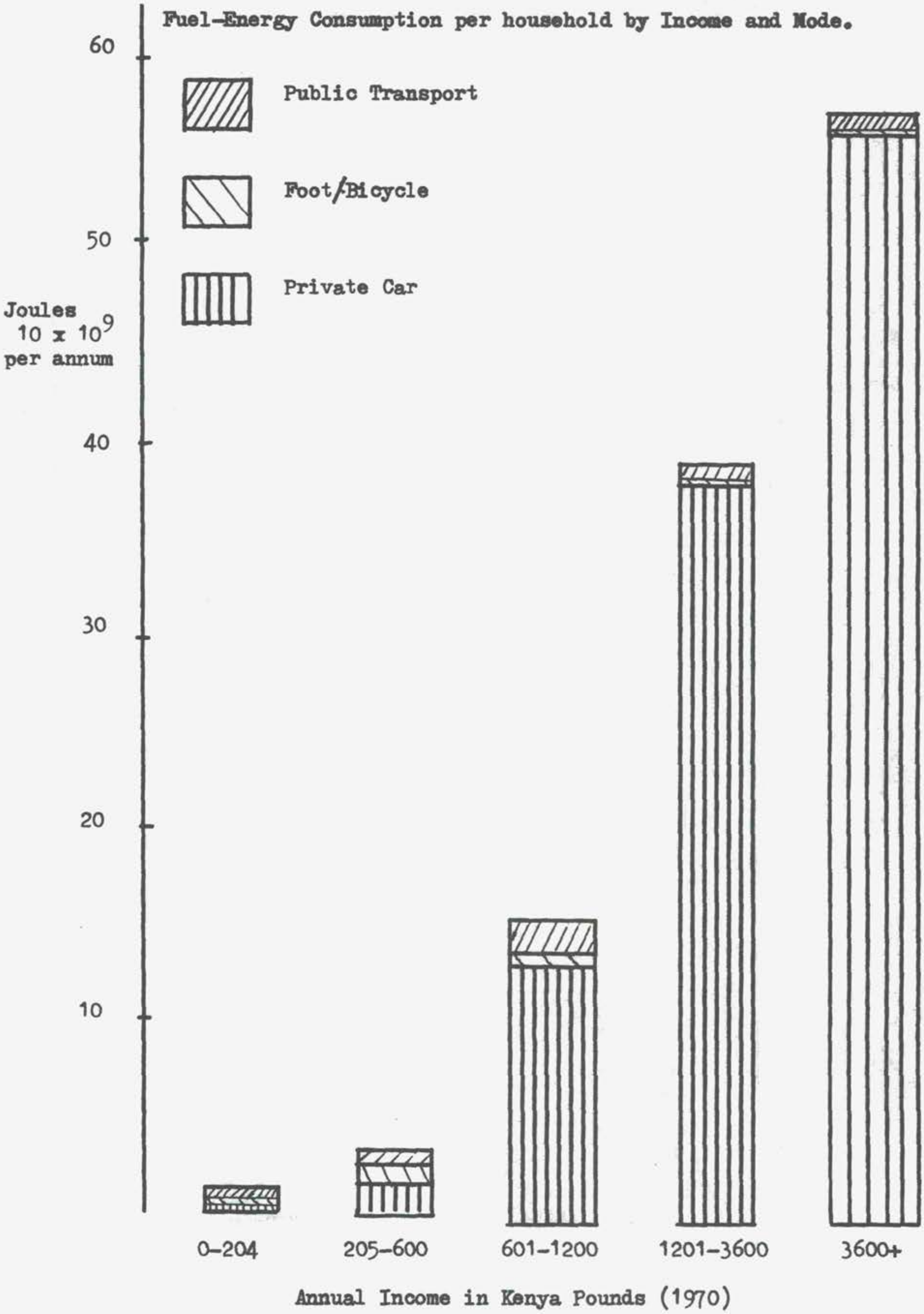
Figure 1. Transportation

Passenger Miles per Household by Income and Mode



Annual Income in Kenya Pounds (1970)

Figure 2. Transportation



FOOD

Procedure

To establish levels of food consumption household market baskets of food purchases are compiled for each income group. These estimates are generated from household expenditure data for "high", "middle", and "low" income households collected by the Central Bureau of Statistics [21] for the purpose of establishing price indices. The prices necessary to convert expenditure information into units of weight are from the 1977 Statistical Abstract.[22] As well as providing the basis for energy calculations, these market baskets can be used to assess the nutrition levels of the different income group.

The method used to estimate the primary energy use associated with the food quantities is based on the embodied energy approach noted earlier. There are three activities through which energy is embodied in the food before it is purchased: agricultural production - energy used on the farm and in providing farm machinery; transportation energy used to transport food from the farms to the retain outlets; and processing - energy use associated with industrial inputs for food processing and packaging, as well as with the commercial activities of food marketing. To the extent possible, these components have been evaluated separately.

Agricultural Embodied Energy[23]

For all produce except highly processed foods, (for which the agricultural energy component is small and the details of the food product inputs are uncertain), agricultural embodied energy coefficients per kilogram of edible food produced are derived. Agricultural energy coefficients for specific crops and farming techniques are available from a number of sources (24-29). In order to ensure consistent results we drew largely on one principle source to provide the basis for the analysis. Leach's technique[24] was chosen due to its flexibility, limited data requirements, and the wide range of conditions and crops to which it has already been applied.

i. Field Crops

The first stage consists of an analysis of the field activities employed to farm a hectare of land for a given crop in Kenya. Where radically different farming techniques are employed to farm for the same crop the analysis is broken down into modern and traditional production. The activity information required relates to the fertilizer and labour inputs, the degree to which machinery is used for plowing, harvesting, spraying, rolling, etc., and the specific types of machinery employed. For grains and certain fruits and vegetables the bulk of this information is available in references 30-32, although it often takes the form of recommendations and impressions rather than statistics. Alternatively in areas where direct information is unavailable we assume similar activities to those carried out for the same crop in countries at similar levels of agricultural mechanization.

The activity descriptions are then translated into energy requirements through the energy coefficients established by Leach. The embodied energy coefficients per kilogram, for both nitrogen and phosphate fertilizers are "best present technology" estimates (Leach

p. 73). Metabolic energy is evaluated on an hourly basis, assuming .8 MJ per hour for men and 8 MJ per hour for oxen.

Tractor fuel consumption is evaluated on a per operation basis as specified in Leach. The operations approach is more suitable than a time based approach since the fuel use per operation is largely independent of tractor size (which is substantially smaller in Kenya). Nonetheless there is uncertainty in the resulting estimates due to our lack of knowledge of soil conditions and types of terrain as well as possible misspecification of operations.

The embodied energy in field equipment per hectare, also from Leach, assumes optimum usage of machinery and is an underestimate of the actual energy requirements per machine on U.K. farms. The less intensive use of the machinery in Kenya should counteract this affect and the coefficients are applied directly.

The resulting agricultural energy coefficients along with the energy form breakdowns, are given in Table 10. These coefficients are not meant to replace on site data gathering. They are, rather, approximations designed to substitute for direct information until it becomes available. A degree of uncertainty is brought about by the lack of precise information on the level of mechanization on farms supplying the urban areas. In addition, for some crops (specifically sugar and certain fruits and vegetables) the information was inadequate for the formation of energy budgets and only rough approximations could be derived.

ii. Livestock and Dairy Production

A similar approach can be applied to livestock and dairy production although different types of activity and energy information is required. In Kenya, where heating requirements are minimal, the principle determinant of the energy inputs is the feed used and its embodied energy. Thus the principle activity considerations are the amounts and types of feed used. The energy coefficients are then embodied energy requirements per unit weight for the different types of feed along with estimates of the embodied energy in the buildings used and any direct energy requirements.

Unfortunately, the country specific information necessary to carry out this analysis in a detailed form was not available, and we were forced to modify the approach. For poultry meat and egg production the same format is used, but the feed weights and embodied energy coefficients for manufactured feed are assumed equal to U.K. figures. The proportion of feed that is manufactured is estimated from total Kenya poultry feed sales. The rest is assumed to be low intensity (2 MJ/kg) grains. A small electricity component is added on to account for the electricity sales to poultry farms specified for the Nairobi area by the East African Power and Lighting Company.[33]

For other meat and milk production cross-national estimates are used in conjunction with a general knowledge of the livestock farming techniques in Kenya. Slesser (ref. 34) estimates the energy ratio (metabolisable energy in food/embodied energy) of low intensity beef production to vary between .35 and 5.4. From the qualitative descriptions of livestock farming given in references 30 and 31, we determined that the Kenyan energy ratio is likely to fall in the lower part of this range and .5 is used as a preliminary approximation. To estimate the embodied energy in milk, we scaled the U.K. figure down by a factor equal to the relative energy inputs in maize production. The energy coefficients along with the assumed fuel from breakdowns are shown in Table 10.

iii. Highly Processed Food and Drink:

The agricultural energy inputs for highly processed food and drink are not analyzed explicitly. Not only is the agricultural energy use a relatively small component of the total embodied energy in these products, but the consumption information is not detailed enough to analyze the raw product inputs. The overall approach used is outlined within the following section.

II. Processing Embodied Energy

i. Field Crops, Livestock and Dairy Production:

For all food products except highly processed food, processing energy is assessed on a per operation basis. Three principle operations are considered: milling, baking, and storage. The coefficients for milling are equal to the direct fuel use for milling in the U.K. Baking is assumed to require the same level of process heat as the U.K. but the associated packaging and other energy requirements are not included. Energy use in storage (including other processing) for milk and meat are taken from electricity sales[33] and production levels[34, 35] of slaughterhouses and creameries in the Nairobi region. Fish storage is assumed equal to that for meat.

ii. Highly Processed Food:

The embodied energy of highly processed food is evaluated as a function of household expenditure. The information available on the energy requirements is limited to a breakdown of the inputs (fuel, water, raw produce, etc) to the Kenyan canning and drinks industries[36] and a detailed analysis of the direct and indirect energy inputs to processed foods in the U.S.[37] In covering U.S. coefficients to Kenyan equivalents, we considered two factors: purchasing power, and product mix. Differences in the price levels of processed food are taken from Kravis[38]. The Kenyan coefficients are built up from disaggregated U.S. figures to account for differences in product mix.

III. Transportation - Embodied Energy

Due to Kenya's small size and Nairobi's proximity to many of the agricultural areas, the transportation of food is only a small component of energy demand. For this reason, the analysis of transportation is limited to an estimation of the average trip length for all agricultural produce and the application of an energy/ton kilometer figure. The resulting transportation factors and the relevant assumptions are given in Table 11.

Table 10. Energy Coefficients (J x 10^3/kg) for Agricultural Products.

	Fertilizers	Direct Fuel (Oil) Use	Embodied Energy of Machinery	Electricity	Human and Animal labour	Processing	Total***
Maize (modern)	1300	1000	330		100		2,700
Grain (traditional)			40		1100		1,100
Maize flour (modern)	1300	1000	330		100	1000	3,700
(traditional)			40		1100	1000	2,100
Wheat flour	2300	2500	1100		450	1000	7,400
Rice	500	4500 4400 (irrig)	2200		500		12,000
Fruit and Veg.*	100	100	100		700		1,000
Meat*	7000	8000	3000	1000	1000	3000	23,000
Chicken	4500**	4400	1400	400	500	1000	12,000
Egg (per egg)	330**	260	50	20	20	40	720
Milk*	1000**	1000	300	300	400	500	3,500
Sugar*	500	1000	500		1000	6000	9,000
Pulses*	300	300	300		2100		3,000
Fish*		8000	1000		1000	3000	13,000
Bread	2100	2300	870		360	7000	13,000

* Energy budgets could not be compiled for these products. Adjusted energy coefficients from other countries were broken down in similar proportions to those given in ref.

** These fertilizer requirements represent the requirements in the production of feed.

*** Totals rounded to 2 significant figures.

Sources and Notes: Agricultural energy coefficients are based on the methodology developed by Leach (ref.10) Information on farming techniques and fertilizer requirements are from Odingo (ref. 6, 17) and Ackland (ref. 1).
Additional information on electricity usage was given by East African Power and Lighting (ref. 7).

Table 11. Per Household Food and Embodied Energy Consumption.

Units	Products	MJ/ Unit	Group 1 0–204 Units	Group 1 Jx10^9/ annual	Group 2 205–600 Units	Group 2 Jx10^9/ annual	Group 3 601–1200 Units	Group 3 Jx10^9/ annual	Group 4 1201–3600 Units	Group 4 Jx10^9/ annual	Group 5 3600 + Units	Group 5 Jx10^9/ annual
kg	Maize flour	3	340	1	420	1.3	420	1.3	120	.36	70	.21
kg	Maize grain	2	61	.25	70	.14	67	.13	25	.05	16	.03
kg	Wheat flour	7	16	.11	35	.25	60	.42	89	.62	110	.71
kg	Rice	12	11	.13	22	.26	55	.66	110	1.32	170	1.09
kg	Other grains	6	1.6	–	2	.01	4	.02	9.4	.05	17	.10
kg	Pulses	3	39	.12	47	.14	60	.15	77	.23	89	.27
kg	Fruit § Veg.	1	180	.18	280	.20	430	.43	630	.63	805	.80
kg	Sugar	9	70	.63	110	.99	.150	1.4	160	1.4	170	1.5
	Staple Crops Sub total			2.41		3.37		4.54		4.67		3.72
litres	Milk	4	140	.56	240	.56	400	1.6	720	2.9	1100	4.4
	Eggs	.7	90	.06	230	.16	340	.24	450	.32	530	.37
kg	Bread products	13	130	.95	110	1.4	150	2.0	190	2.5	220	2.5
	Dairy § Bakery Sub total			1.57		2.52		3.84		5.72		7.67
(kg)	Meat	23	50	1.2	83	1.9	120	2.8	130	3.0	140	3.2
(kg)	Chicken	12	3.4	.04	7.5	.09	15	.18	25	.30	35	.42
(kg)	Fish	13	6.3	.08	18	.23	33	.43	51	.66	67	.27
	Meat Sub total			1.32		2.22		3.41		3.96		4.49
kwh	Beer § Drinks	5	130	.65	290	1.5	400	2.4	730	3.7	950	4.8
kwh	Canned, frozen § prepared food	7	180	1.3	410	2.9	700	4.9	1200	8.4	1700	12.0
	Highly processed Food sub total			1.95		4.4		7.3		12.1		16.8
	Transportation factor			.96		1.6		2.0		2.5		3.3
	TOTAL			8.23		14.11		21.09		28.95		37.98

IV. Spoilage:

A significant proportion of many crops spoil before reaching consumers. This affect can be incorporated by multiplying the energy coefficients by 1/1-s, where s is the proportion of food spoiled. Whether the transportation coefficient should be increased by this factor depends on the point at which the spoilage occurs.

Unfortunately we could obtain no information on spoilage. This omission has probably led to an underestimation of the embodied energy coefficients. In further analysis this factor should be taken into account.

Discussion

The food energy profile is illustrated in Figure 3. The analysis of the results is constrained by the level of uncertainty. Crop specific interpretations are out of place in the absence of detailed field data. The importance of highly processed food and drinks illustrates the need for further research into the specific technologies and fuels used for food processing in Kenya. There are, nonetheless, a number of general implications.

To simplify the analysis of the variations of embodied energy in food with income we have divided food consumption into four types: staple crops (grains, sugar, fruits and vegetables) dairy and bakery products, meat, and highly processed foods.

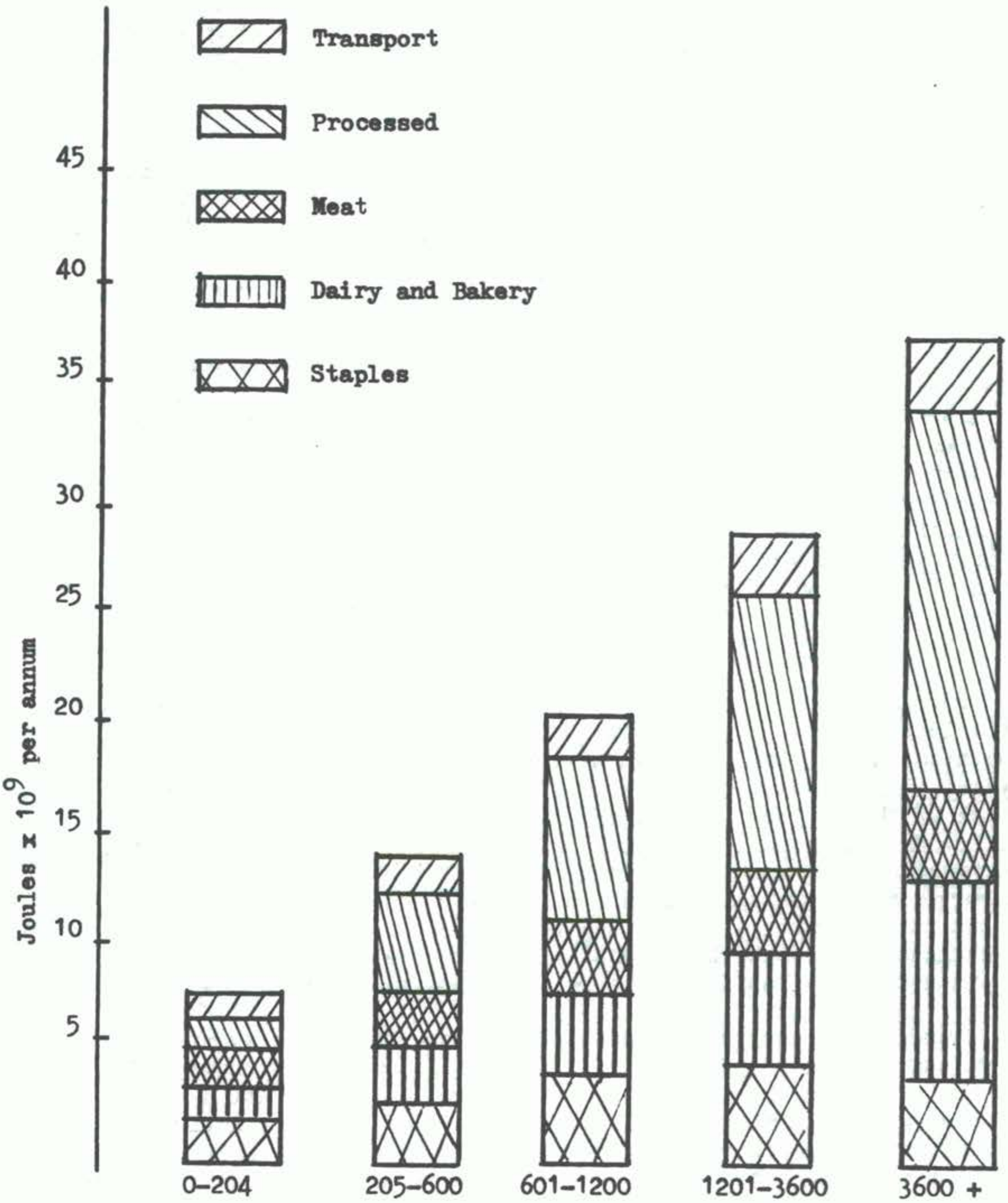
It would appear from figure 3 that part of the variations in embodied energy of food with income is brought about by the consumption of more energy intensive foods at upper income levels. Households at all income levels appear to have a basic consumption of grains and fresh produce which grown slowly, with income, slightly more doubling between the lowest and the highest levels. Meat, dairy and bakery products which generally require larger energy inputs to meet protein and food energy requirements vary more significantly with income, increasing by a factor of four. The most significant variation, however, is in the highly processed foods and drinks. From less than one quarter of the embodied energy for the lower income level the energy in processed food increases eightfold and accounts for half of the embodied energy of the highest income group.

Footnote for Table 11

Sources and notes:

Food consumption figures for different income groups are from "Consumer Price Indexes, Lower, Middle and Upper Income"[1]. Implicit income elasticities and prices for the Statistical Abstract (ref.2) were used to adjust the figures to the income groups above. Agricultural energy coefficients are taken from Table 1. Results were checked for consistency against production figures from reference 14 and 15. Transportation factors assume an average distance of 100 km from farm to city center and an energy coefficient of 4.4 MJ/kg, the requirements of a 7 ton truck going 3/4 loaded into the city and returning to the farm empty. Source for energy/SK coefficients for highly processed foods are given in text.

Figure 3. Food-Embodied Energy per Household.



Annual Income in Kenya Pounds (1970)

RESIDENTIAL CONSTRUCTION

Procedure

New housing requirements can be broken down into: a replacement component; a growth component and; a component representing the needs of existing households with no adequate dwellings. In a growing area such as Nairobi the replacement of existing dwellings is only a small fraction of the total demand for new housing. In addition, the housing shortfall which exists predominantly at low income levels does not appear to be diminishing. The major factors influencing the number of housing units required are, therefore, the natural rate of growth and the migration.

All new households are assumed to require dwelling units. The growth rate for each income group therefore represents a proportion of households demanding additional units. A factor of .6% is added to the growth rates to account for the replacement of old units. This factor is equal to the proportion of dwellings which would no longer be habitable assuming a construction lifetime of 40 years and a constant population growth rate of 6%.

For each income group the new dwelling units are assessed in terms of their floor space and capital requirements. These characteristics are derived from the capital availability at different income levels and the square feet of floor space observed in existing dwellings. As such, no improvements in the housing situation for currently houseless families are assumed and the new housing characteristics for the lower income groups fall below the minimum housing standards specified by the Nairobi City Council. Since, in addition, the growth rates assumed are slightly lower than historic trends a deterioration in the housing situation is implicitly assumed to occur if high growth rates continue.

For all income groups 20%[39] of the household income is assumed available for housing requirements. Payments at this level are translated into capital outlays over an amortization period of 15 years at an interest rate of 10%. A 15 year period was chosen instead of the 20 year period used in the Urban Growth Strategy[40] to allow for the more restrictive current practices, and to make the results consistent with floor space and construction cost estimates. To determine the average capital outlays per household, the capital cost per unit is multiplied by the proportion of households requiring additional units. The resulting construction cost figures by income provide the basis for the embodied energy calculations.

Ideally the next stage in the analysis would be an examination of the cost and materials breakdown for residential construction for different income groups. Since only very general information was available to us on the construction industry, however, we derived total embodied energy coefficients on the basis of alternative assumptions on the energy prices and construction techniques. In the construction industry in Kenya the energy intensity (measured as the ratio of the value of energy inputs to the value of output) was .0189 (in 1971) compared with .0165 in Portugal[41], .0122 in Spain, and .0116 in

Yugoslavia. For both direct and indirect energy requirements the energy intensities become .0655 for Portugal, .0862 for Spain and .0647 for Yugoslavia. The small variation among these figures would seem to imply that the application of a generic energy coefficient is an adequate approximation. However, since the energy intensity of residential construction alone could be substantially lower, only an upper limit has been identified. Further research on the construction techniques and materials will allow a more accurate estimate to be made.

The upper limit to the energy coefficient shown in Table 12 is based on an analysis of the inputs to the construction of new buildings in Kenya in 1971. From the I/O table for Kenya[42] and a survey of industrial productions[43], we obtained a breakdown of the inputs to building construction for the broad categories; fuel, transportation, wood, rubber, point, primary mining and quarrying products, metal products and non metallic mineral products*. These input values are expressed as fractions of the total output of the construction industry in Table 12. Direct fuel purchases are assumed to be exclusively oil products and the fuel values are translated into energy inputs at the existing diesel fuel prices (230 MJ/Ks)[44]. Transportation inputs are split equally between fuel consumption and vehicle purchases and maintenance. In assessing the embodied energy in materials we assume that the production techniques are similar to the U.S. and apply U.S. energy I/O coefficients[45] after adjusting for known price differentials[46]. The resulting estimate of 190 MJ/f is likely to be an overestimate, not only because of the technologies assumed, but also because nonresidential building, which is included in this coefficient, tends to be more energy intensive than residential.

Two spot checks are applied to the resulting embodied energy per unit figures. For the upper income group the embodied energy of the 1500 ft. housing unit of 720 1100 Joules $\times 10^9$ appears consistent with an average value of 1100 Joules $\times 10^9$ for a single family 1500 ft.^{2} house in the U.S. as estimated by Hannon[47]. For the lower income group we derived an estimate for a 100 ft.^{2} unit, assuming a concrete block construction with steel sheeting for the roof, built by hand**. Applying U.S. coefficients to these materials and .8 MJ/hr to the labour, the total energy requirements are 19×10^9 Houles. Although the inclusion of the transportation of materials and miscellaneous inputs would be expected to raise the figure by up to 40%, 34×10^9 Joules appears to be slightly high. Since the addition, many of the very low income households currently use recycled materials in their construction it would appear that the scale is relevant solely to middle and upper income groups. However, since even under the scale given, construction is only a minor component of energy demand at low income levels we have not attempted any adjustment.

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* We assume this category consists predominantly of concrete blocks.

** The assumed inputs are: 370 8"x8"x16" blocks, 300 lbs steel sheeting, 1/3 yard^3 cement and 320 hrs of labour.

Table 12.

High Case	Wood and Sawmill Products	Rubber Products	Paint	Non-Metalic	Mach. Metal	Mines + Qu	Transport	Direct Fuel Use
£ Input/£ Output	.049	.008	.015	.091	.171	.042	.064	.0086
Jx10/£ Output	12	2	5	42	39	19	34	37

Total 190

Table 13.

Income Group (K£/annum)	Average Income	New DU/ Hsehld	Exp/ Hsehold	Cap Cost(L)/ Unit	Ft^2/Unit	$Jx10^9$/Unit	$Jx10^9$/Unit	$Jx10^9$/Hsehld
0-204	110	.064	23	180	100	190	34	2.2
205-600	350	.064	71	540	170	190	100	6.4
600-1200	880	.064	180	1300	540	190	250	16
1200-3600	2200	.064	430	3300	1000	190	630	40
3600+	4000	.064	800	6000	1500	190	1100	70

Sources and Notes:

New dwelling units per household: is equal to the assumed growth rate (5.8%) plus a component representing the replacement requirements assuming a 40 year life of construction and a constant historical growth rate of approximately 6%,

$$\frac{(1.06^{41} - (1.06)^{40}}{(1.06)^{41}} = .0055.$$

Ave. Yearly Exp. available per household is assumed to be 20% of the household income. This figure, taken from the "Urban Growth Strategy" (par. 5.15). For elaboration see Note 1.

Capital Cost Per Unit: dervied from the average yearly expenditures amortized over a 15 year period at 10% interest. See text for an explanation of period length chosen.

Floor Space/Unit: these figures are based on the capital cost estimates and the price per square foot quoted in the "Metropolitan Growth Strategy"2. Ave. Cap. Cost/Household: New DU/Household x Capital Cost per Unit.

Discussion

The final profile of energy use in construction is given in Figure 4. Due to the uncertain nature of several assumptions on which the range is based and the lack of reliable information on energy consumption for construction within Kenya, the results for this sector must be viewed with skepticism. It is evident, nonetheless, that residential construction is an important component of energy demand. The U.S. household average embodied energy requirements in housing (52×10^9 Joules (ref. 48)) falls within the range for the upper income group. The Swedish energy requirements (ref. 49) fall within the range of the middle income group although their average income is more than double that of Nairobi's middle income group. These high energy requirements are exhibited inspite of the relatively low energy intensities assumed and are brought on by the high population growth rate in Nairobi.

In interpreting the results it is important to note that the range specified is based largely on embodied energy coefficients in the U.S. If residential construction is indeed as important an energy consuming sector as these results imply it would be worthwhile to carry out more detailed analyses based exclusively on Kenyan data.

SERVICES

The services considered are: public lighting, water supply, schooling, medical care, and garbage collection. The nature of these services makes it difficult to determine who "uses" them and to what extent one income group "uses" them more than another. In addition, information on the non-electric energy consumption proved unattainable. For these reasons, the following analysis of the services sector must be viewed as very preliminary.

For each service the electrical energy requirements (Table 14) were taken from electricity sales data for the Nairobi area. To establish relative usage among the income groups, quantifiable surrogates (Table 15) were applied when possible.

The resulting energy profiles are shown in Table 16. The absolute magnitude of the energy use in services appears to be very small. Naturally, the inclusion of non electrical energy use and the embodied energy in service construction would increase the energy figures, but it would be unlikely to raise them to a point where services would be considered an important energy consuming sector. The important implication is, rather, that the services are non energy intensive and that the future supply of services is unlikely to be constrained directly by energy shortages.

Figure 4. Construction. Embodied Energy per Household.

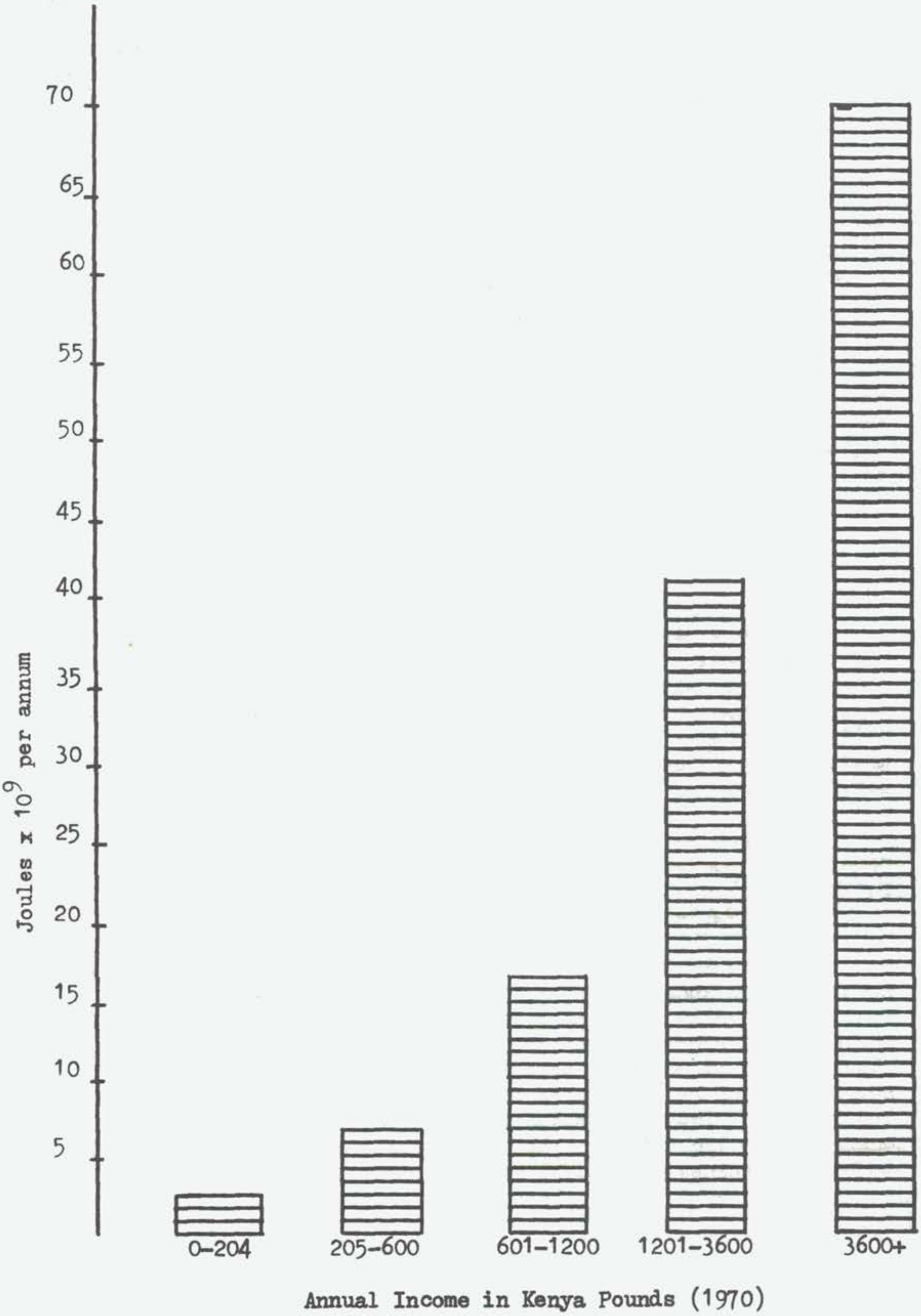


Table 14.

Service	Approximate Annual Electricity Consumption (76/77) 000 kwh	Distributed among households according to:
Water Supply	7,800	gallons water/day consumed
Primary Schools	4,400	distributed evenly
Secondary Gvt. Schooling	830	Ksh/ann. spent on gvt. schooling
Secondary Pvt. Schooling	2,200	Ksh/ann. spent on private schooling
Universities	6,600	distributed evenly among upper 3 income groups
Medical Care	8,200	distributed evenly
Public lighting	7,600	distributed evenly
Garbage collection	-	No data available

Table 15. Per Household Weights.

	Units	Sub Sector	0-204	205-600	600-1200	1200-3600	3600+
	gallons/ day	Water Supply	14	52	120	208	320
1974	Ksh/ month	Public Schooling	6.5	12		27	31
	Ksh/ month	Private Schooling	3.8	11	26	57	91
	-	Higher education	0	0	1	1	1
	-	Medical care	1	1	1	1	1
	-	Public lighting	1	1	1	1	1
	-	Garbage Collection	0	0	0	0	0

Sources: Water consumption is estimated in "Water, Sewage and Electricity," Technical Appendix No.7," Metropolitan Growth Strategy. Expenditure data was collected for "Consumer Price Indices, Nairobi," CBS, 1977.

Table 16. Services - Per Household Electricity Consumption Joules x 10^6 (Assuming efficiency of .31)

Service	Income Group (KI/Annum) 0-204	205-600	601-1200	1201-3600	3600+
Street lighting	470	470	470	470	470
Water supply	34	123	285	494	760
Hospitals	500	500	500	500	500
Schooling	44	109	212	428	641
Higher education	-	-	1060	1060	1060
Total	1048	1202	2527	2952	3431

SUMMARY AND CONCLUSIONS

The conclusions given in this section are meant to be indicative of the implications which can be drawn from the energy profiles and should not be taken as definitive. As mentioned in earlier sections, there are a number of uncertainities which could not be avoided in the short time frame of this preliminary study. A continuation of the study, incorporating a larger household survey and a more in depth analysis of the energy use associated with the various activities would allow a broader range of conclusions to be drawn and provide corroboration (or refutation) of our initial hypotheses.

Overview of Results

The per household energy use profiles are summarized in Table 17 and displayed in the form of a histogram in Figure 5. As income rises, several changes in the patterns of energy use can be identified. The total per household primary energy use is shown to increase rapidly. Residential direct uses, although remaining the highest energy consuming activity sector, decrease in relative share of energy use with increasing income. From the more detailed residential profile including Basic Energy Demands we know that within the lower part of the income range the amenity level increases more rapidly than primary energy due to shifts in the fuel/technology combinations away from the use of the jiko. The embodied energy in food varies less with income, increasing by less than a factor of five over the income range. The increase that does exist appears to be brought about by increasing amounts of food consumed (presumably reflecting higher levels of nutrition) and a larger share of more energy intensive food products. The energy use in transportation is shown to be the most income elastic; from less than 3% of the energy use in the poorest group it increases by a factor of 60 over the income range and accounts for more than 20% of the energy use at the highest income level. This is the result of both passenger miles and energy use per passenger mile increasing almost 8 fold. The embodied energy in housing construction also appears to have a high income elasticity, with income and energy use increasing proportionally. This result is implicit in the estimation procedure and relies on the housing expenditure figures used. The preliminary nature of the estimates for the services sector precludes an interpretation of the variation with income.

Table 17. Per household primary energy demand by income and activity sector.

($J \times 10^9$)
Income Group

	1	2	3	4	5
Residential	19.3	18.8	46.5	71.6	104.0
Transportation	.89	3.31	15.27	39.73	60.00
Food	8.23	14.1	21.09	28.95	37.98
Construction	2.2	6.4	16.	40.	70.
Services	1.05	1.20	2.53	2.95	3.43
Total	31.7	43.81	101.	183.	275.

Accompanying the changes in the magnitude of primary energy consumption with income are shifts in the fuel mix. The fuel mix associated with direct energy consumption is given in Table 18. The fuel shifts with increasing income are striking. Wood and charcoal use which accounts for 65 percent of the fuel consumption of the lowest income group falls off steadily and only represent 3 percent of the fuel use of the highest income group. Kerosene usage falls off even more sharply; from 32 percent of the fuel use in group 1 to virtually zero by group 4. Liquid gas appears to be significant solely among the middle income groups. Electricity and gasoline consumption are highly income elastic and combined supply almost all of the direct energy needs of the highest income group.

Table 18. Per household direct energy consumption by fuel form and Income.

($J \times 10^9$/annum)

Fuel Form/Income	0-204	205-600	601-1200	1201-3600	3601+
Wood and charcoal	13	13	9.0	7.0	4.9
Kerosene	6.4	3.0	2.6	-	-
Liquid Gas	-	1.6	9.5	8.8	.7
Gasoline and Diesel	.62	2.9	14	40	57
Electricity	-	1.7	25	56	98

An extrapolation of the per household (direct and indirect) energy demand figures to total energy consumption figures for Nairobi yields the estimates given in Table 19. The total primary energy required to support the activities of Nairobi's households is estimated at 16% Joules $\times 10^{15}$. Direct energy use (residential and transportation) accounts for 59% of the demand, the rest being embodied in the food (21%), housing (18%) and services (2%). The total primary energy use associated with the different income groups is best illustrated in Figure 6. The poorest 59% of the population are shown to

Figure 5. Per household Energy Use by Income and Activity.

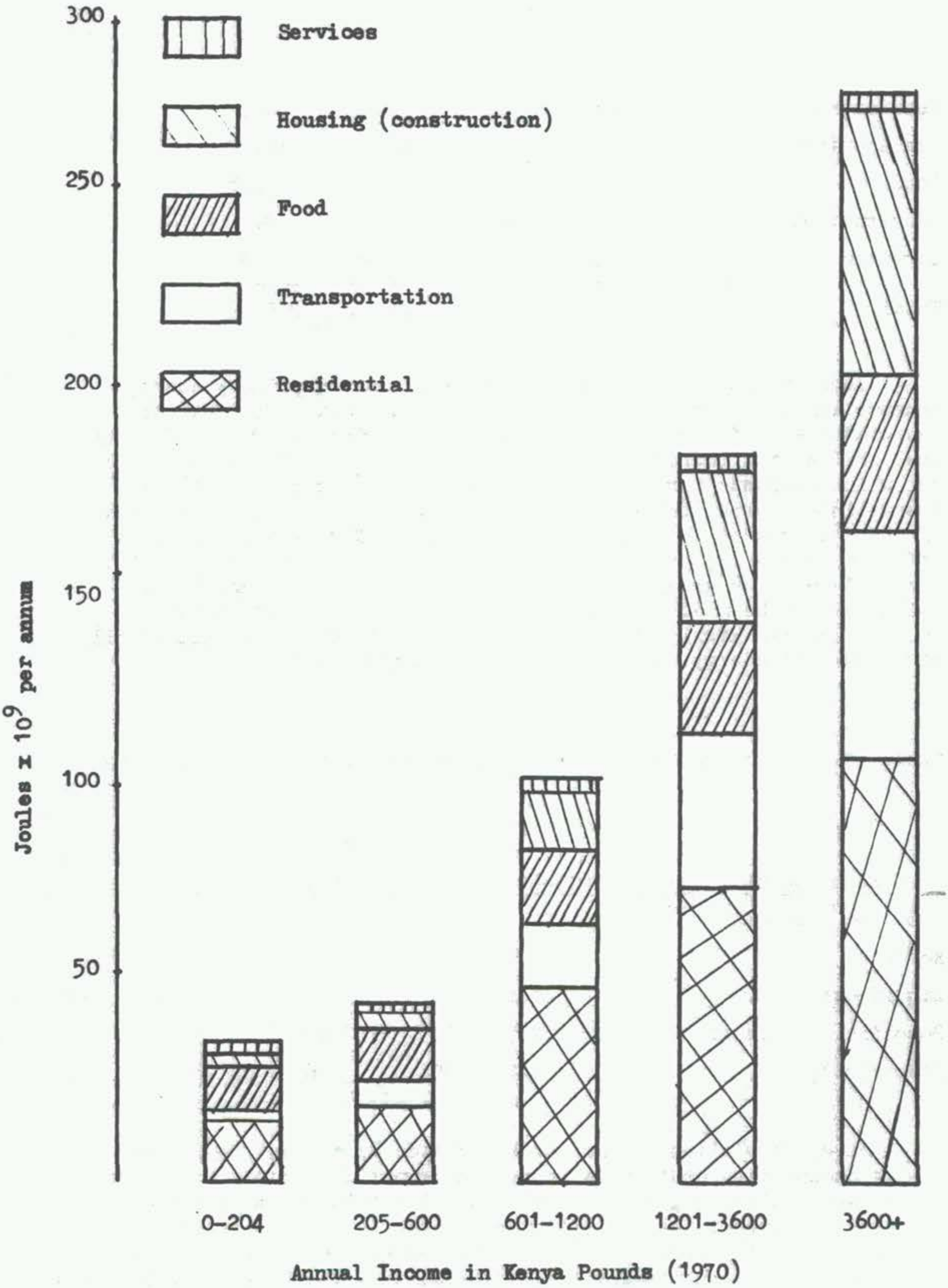
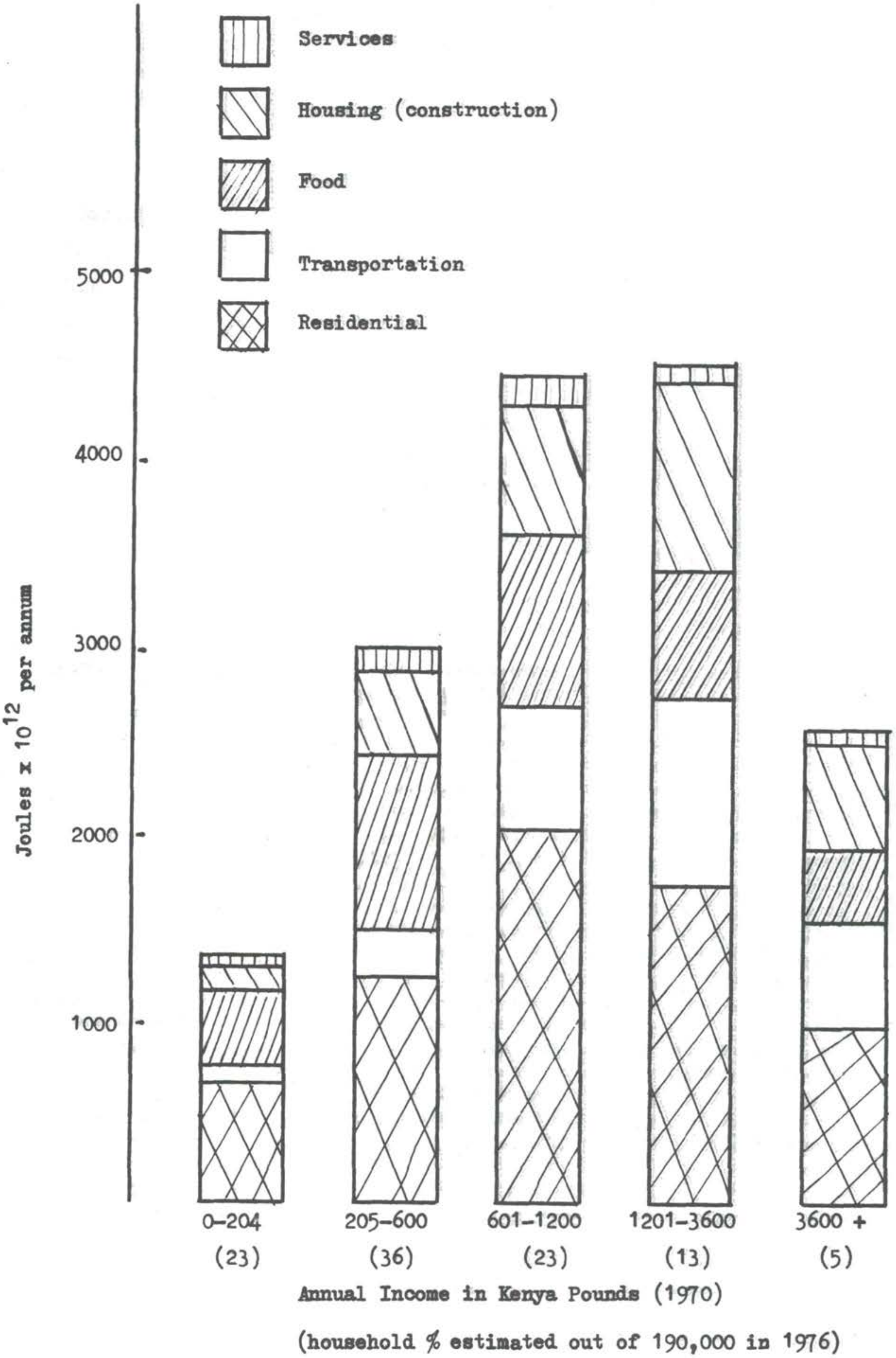


Figure 6. Total Energy Use by Income Group



account for approximately 27% of the energy consumption, while the richest 18% account for almost 45% of the energy consumption.

Table 19.
Total primary energy demand by income group and activity - 1976
Estimates

. ($J \times 10^{12}$)
Income Group

	1	2	3	4	5	Total
Residential	843	1,290	2,030	1,770	988	6,920
Transportation	38.9	226	667	981	570	2,480
Food	360	964	922	715	361	3,320
Construction	96.1	438	699	988	665	2,890
Services	45.9	82.1	111	72.9	32.6	345
Total	1,380	3,000	4,430	4,530	2620	16,000
# Households 1976	43,700	68,400	43,700	24,700	9500	

Note: All figures rounded

Policy Issues

The energy use profiles imply that the growth and development of Nairobi may require large energy inputs regardless of the structure of the industrial development accompanying this growth. In the absence of changes in either the household activity patterns or the modes through which energy is used to support these activities, the increasing per capital income would also appear to result in an increasing dependence on commercial fuels. At the same time the profiles suggest some areas in which interventions could aid in preventing these "predictions" from materializing.

The transportation sector is particularly important in this regard. The energy requirements for transportation are currently highly income dependent. At the same time the energy characteristics of household transportation are influenced by the demographic and infrastructural characteristics of the city. Urban planning, through its effects on residential, commercial and industrial location and the transportation infrastructure could alter the average trip distances and the mode split without putting constraints on the number of trips taken. The situation in Mexico City, described briefly in Appendix A, highlights the importance of transportation energy considerations on urban planning.

The energy characteristics of residential construction could also become an integral part of urban planning in Nairobi. The energy use profiles show relatively large energy requirements for construction. Even if the housing situation is deteriorating faster than we assumed and the real energy demands are significantly less, the potential impact of implementing less energy intensive construction techniques and materials would still be significant. Already the government is responsible for a large proportion of the new construction, especially for the middle income groups. A study of low income housing in Nairobi has illustrated that the market mechanisms are not operating efficiently and that some form of intervention is required in low income housing. Thus the intervention would not be for the sake of energy conservation alone.

The energy profiles also illustrate the importance of ensuring adequate energy resources to meet the needs of the urban poor. Energy use at the lowest income levels goes predominantly to meet basic human needs. Food and food preparation (approximately 80% of energy uses in the two lowest income groups) constitute the bulk of energy consumption. The low income diet consists largely of low energy intensity foods. Direct residential energy use cannot be cut back without lowering activity levels (cooking, lighting, etc.) or increasing the efficiencies of energy use through the purchase of more efficient (and currently more expensive) end use devices. Transportation is already mostly pedestrian. The housing is currently constructed largely with recycled materials. Services are minimal. At the same time, the level of energy used in supporting the activities of the poor (1.4×10^{15} Joules for Group 1 and 3×10^{15} Joules for Group 2) is a significant portion of total energy demand.

Although the poor themselves have little flexibility in their household energy budgets, there are several options open to the government which could decrease the reliance of low income groups on energy. In particular more efficient cooking devices could play a large role. The efficiency of the jiko appears to be approximately 20%. According to our results, increasing this efficiency to 30% would result in a 14% savings in the average poor household's total (direct and indirect) energy use with no change in cooking patterns. A changeover to electric lighting from kerosene would also appear to result in energy savings and would liberate kerosene for uses for which it is relatively more efficient. Kerosene lighting has a relative affectiveness of .1 while the relative effectiveness of kerosene cooking appears to be between .3 and .4. Changes of this nature would require capital investments infeasible for the low income households and government help would be required.

The patterns of direct (residential and transportation) fuel consumption are also important to government domestic pricing policies and, indirectly, to supply strategies. As illustrated in Figure 5 the fuel mix differs widely among income groups. It would appear, therefore, that the first order incidence of domestic energy price increase is highly dependant on fuel form. In the absence of detailed price elasticity information, fuel consumption estimates of this type are the best means of determining those groups most affected by a given fuels domestic price increases. Certain supply strategies can also be assessed in this context. For example, unless usage patterns alter substantially, strategies aimed at providing an abundant supply of low (per unit) cost electricity for domestic consumption will have their major impact on middle and upper income households. The poor appear to be either unconnected to the electric system or wired solely for lighting. Research and development in charcoal production for domestic consumption, on the other hand, would appear to be a primary interest of the urban poor.

Research needs

1. Profile refinement

Before further implications and conclusions are drawn from the profile, or the profile is used as a tool for energy conservation assessment and demand projection, several sections require revision. Of primary importance is an analysis for each section and group of the specific processes and efficiencies and refinement of the resulting energy intensity coefficients by fuel form. Such information would be valuable for other forms of energy analysis in addition to providing a strong foundation for the household profiles.

For the most part, individual improvements are mentioned in the earlier sections of this report. Recapitulating all the revisions suggested at earlier points is not overly worthwhile. Certain important improvements merit reiteration however, and various observations are appropriate.

In the transportation sector, trip length appears to be the variable of the largest uncertainty and whose value will be most affected by growth. The effects of growth on the group dependent trip frequency rates probably will not be as severe, at least in the immediate future. Updating of the information about both variables is important.

In the direct use sector, a more extensive survey is required. Its focus can proceed along two different lines or along both lines simultaneously:

i. An extended investigation of a small number of representative households from each group can be made to gain a detailed knowledge of the breakdown by activity of household consumption.

ii. A large-scale survey of many households can be made to acquire statistically significant knowledge about fuel consumption, and of the appliances present in the home.

Ideally, the two approaches converge since the requirements for choosing a representative group household should be that its consumption reflects that of all households in the group, and to know if a household's consumption matches that of the others, a statistically significant number of households from the group must be surveyed. In practice, furthermore, one would hope that a knowledge of the breakdown by activity of household consumption could follow from a survey of many households. For the lower income groups, in fact, where household consumption only occurs from two activities, such an extrapolation appears possible. For the three highest groups, however, since individual households back a quantitative knowledge of the breakdown by activity of their consumption, the cost in terms of man-hours appears large for accomplishing a survey of many households over the extended period of time required to gain a quantitative understanding of the breakdown by activity of consumption.

The most appropriate approach would integrate the two types of survey for the three highest groups and carry out the large-scale variety for the lower two groups.

In all cases, the ad hoc procedures used in the analysis of direct usage were requred to estimate the breakdown by activity of household consumption. Information about total fuel consumption was always available. Information about rates of fuel consumption by different devices was not nearly as accessible.

The most important revisions suggested by the study in the analysis of food and construction are related to the projection and refinement of the energy intensity coefficients; Joules (by fuel form) per kilogram of food type for food, input energy (in Joules) by fuel form per Kenyan shilling of output by construction. In food, the country specific information required in the estimate of energy per kilogram of goods from livestock and dairy production is especially sparse. In construction, ideally, a different set of construction energy intensity coefficients based on a material by material analysis would be derived and an extrapolation would be made of the amounts of each material present in the homes of households from each group. Probably, a more tractable alternative method would be to derive values for input energy per Kenyan shilling of construction output using the approach similar to the one followed by the Gordian Associates.

In all sectors, our knowledge of energy intensity coefficients requires refinement. In the direct use sectors the energy present in charcoal in its fuel form is not known for all varieties of charcoal present in Nairobi; in the transportation sector, the loading factor of the matatu, the number of passenger-miles per vehicle-mile, is unknown, for example.

The text reveals other instances where revision would be appropriate. In this section, the attempt was to summarize some of the more important areas where refinement is appropriate.

Profile Extensions

Changes in specific variables can be introduced into the profiles to provide technology assessments, projections or sensitivity analyses.

Technology assessments (generally evaluations of more energy efficient devices) are particularly appropriate to the direct energy using activities for which relative efficiencies can be specified. The procedure for introducing new technology into a similar framework is given in "Less Developed Countries Energy System Network Simulator"[51]. Briefly, the new technology can be represented by the addition of a link between the activity level and the energy consumption. Keeping the activity level constant the profile is then perturbed by shifting the share of the activity to be met by the new technology away from the technology being replaced and through the new link. The implied energy use changes are thereby derived. Several possible substitutions have been identified in earlier sections of this study. Particularly relevant for the low income households are more efficient charcoal stoves. Electric mass transport systems, less energy intensive building materials and spoilage control could also be evaluated. The assessments need not be limited stricly to technologies. Changes in residential location, for example, could be evaluated through its effect on trip length.

The use of the household profiles for projections cannot be discussed in detail at this stage. Several points are, however, worth mentioning. The use of an energy profile from one time period for projection purposes entails several restrictive assumptions. To provide a base case future scenario from which to work, projections of the city's population by income groups are required[52]. Activity levels, measured in basic energy demand, household trips, floor space requirements, market baskets and services provided can initially be assumed constant over time within any given income group. Although in practice shifts may result between the activities, a general increase or decline in activity levels would be inconsistent[53] with constant real income. The profile can then be perturbed (on the basis of assumed changes in technologies and energy intensities) in the manner discussed above. The comparison of Nairobi and Mexico City (Appendix A) highlights the need for independent projections of trip length. Additional modifications can be made as required.

NOTES AND REFERENCES

1. The terms, basic demand and fuel specific demand, are taken from Beller, M. "Sourcebook for Energy Assessment", BNL 50483, Dec. 1975. Our convention will be to assign most electrical devices efficiencies of 100% and to define the efficiency of a device as its effectiveness relative to the comparable electricity technology of lowest absolute efficiency. On occasion, when a particular efficiency is not well-known, we treat the variable as an adjustable parameter whose value is determined self-consistently from the equation relating basis to fuel specific demands, (see footnote 7).

2. A copy of the home survey is included as an Appendix C.

3. East African Power and Lighting billing information was supplied by R, McDougall.

4. Room number, household size, light bulb number and average wattage per light bulb values were taken from the survey.

5. Various studies have shown that the quantity, wattage connected for lighting per person-room should be invariant over households of conparable living standards (e.g., see Mow, C.C., et al. Rand Report K-995-NSF/CSRA, March 1973).

6. A value of 4.8 kwh/person-room-year of basic demand for lighting was assumed. Though the value is an appropriate U.S. average, the value falls well below the minimum standards for lighting established by the American Home Lighting Institute (60.49 kwh/person-room-year). (see Mow, C.C. et al., "A Methodology for Projecting the Electrical Demand of the Residential Sector in California". Rand Report R-995-NSF/CSRA, March 1973).

7. This is an example of an instance in which we treat the efficiency of a fuel-technology combination as an adjustable parameter whose value is determined self-consistently; the development of this method evolved from work done by two of the authors in the construction of a methodology for analyzing rural energy usage patterns.

8. The market basket is given in this report.

9. Ibid., Mow, et al., Rand Report R-995-NSF/CSRA.

10. Nathans, et. al. "The Planners Energy Workbook," BNL 50633, June 1977, and "Patterns of Urban Household Energy Use: The Case of Mexico City".

11. "Metropolitan Growth Strategy", Chapter 4, Colin and Buchanaan (for Urban Study Group), Nairobi, 1974.

12. Matatu refers to an extremely inexpensive taxi-bus having a high load efficiency; the matatu was illegal in Nairobi until recently.

13. Estimate of bus and automobile load factors were taken from Shouka, D.B., et. al., "Transportation Energy Conservation Data Book: Edition 2". Oak Ridge National Laboratory Report No. 5320, October 1977.

    The estimate of the matatu fuel efficiency was taken from Everall, P.F. "The Effects of Road Traffic Conditions on Fuel Consumption". Transport and Road Research Laboratory Report, No. LR 226, Bracknell Berkshire, England, 1968.

14. "Patterns of Urban Household Energy Use in Developing Countries: The Case of Mexico City," Chapter 1.

15. Ibid. "Metropolitan Growth Strategy," Chapter 4.

16. Ibid. "Metropolitan Growth Strategy," Chapter 4.

17. Ibid. "Metropolitan Growth Strategy," paragraph 4.21 and following.

18. Ibid. Shanka, D.B., et. al. ORNL Report No. 5320, October 1977.

19. Ibid. Everall, P.F., Transport and Road Research Laboratory, Report No. LR 226, Bracknell, Berkshire, England, 1968.

20. "Patterns of Urban Household Energy Use: The Case of Mexico City", pp. 7-15.

21. Central Bureau of Statistics, Kenya, "Consumer Price Indices: Nairobi", March 1977.

22. Central Bureau of Statistics, Kenya, "Statistical Abstract 1977", 1977.

23. Agricultural embodied energy refers to the energy input to food production up to the point at which the produce leaves the farm.

24. Leach, G., Energy and Food Production, IEED, IPC Science and Technology, Press, Survey, 1976.

25. Makhijani, A., and A. Poole, Energy and Agriculture in the Third World, Balinger, 1975.

26. Pimentel, D., "Food Production and the Energy Crisis", Science, Nov. 1973, pp. 443-449.

27. Slesser, M., Food, Agriculture and the Environment, edited by J. Lanihan and W. Fletcher, Blackie Press, London, 1975.

28. Slesser, M., "How Many Can We Feed?", The Ecologist, 1973, pp. 216-220.

29. Steinhart and Steinhart, Energy: Sources, Use and Role in Human Affairs, Duxbury Press, 1974.

30. Ackland, J.D., East African Crops, F.A.O., Longman, 1971.

31. Odingo, R.S., The Kenya Highlands, East African Publishing House, 1971.

32. Odingo, R.S., "A Study of Agrarian Change in Kenya", F.A.O., June 1973.

33. East African Power and Lighting, "Commercial Consumer Statistics, Tariffs 4 and 5", Dec. 1977.

34. Ministry of Agriculture, Kenya, "Annual Report 1977", CBS, 1977.

35. Ministry of Agriculture, Kenya, "Economic Review of Agriculture" 4 quarters, 1977. CBS, 1977.

36. Central Bureau of Statistics, Kenya, "Surveys of Industrial Production, 1970-71", June 1973.

37. Bullard, et. al., "Net Energy Analysis: Handbook for Combining Process and Input-Output Analysis", Centre for Advanced Computation, Urbana, Illinois, 1976.

38. Kravis, et. al., A System of International Comparisons of Gross Product and Purchasing Power, John Hopkins University Press, Baltimore, 1975.

39. Expenditure data is available from Gordian Associates and Kenya Statistical Digest. Although there appears to be some descrepancies among the estimates and slight variations with income (the CPI estimates 21%, 16%, and 26% for the low, middle and high income groups), 20% as specified in the Urban Growth Strategy[2] appears to be an adequate approximation.

40. Urban Study Group, "Metropolitan Growth Strategy", Chapter 5, Nairobi, 1974.

41. Energy intensities for Portugal, Spain and Yugoslavia are estimates given in: Gordian Associates "LDC Energy Supply/ Demand Balances and Financing Requirements", Feb. 1978. No other countries were cited.

42. Central Bureau of Statistics, Kenya, "Input/Output Tables for Kenya, 1971" August 1976.

43. Central Bureau of Statistics, Kenya, "Surveys of Industrial Production, 1970-1971", June 1973.

44. Central Bureau of Statistics, Kenya, "Statistical Abstract 1977", 1977.

45. Bullard et. al., "Net Energy Analysis: Handbook for Combining Process and Input-Output Analysis" (1976), C.A.C., Urbana, Illinois.

46. I.B. Kravis et. al., A System of International Comparisons of Gross Product and Purchasing Power (John Hopkins Univ. Press, Baltimore, 1973).

47. B. Hannon et. al., "Energy and Labour in the Construction Sector", Science, (Nov. 24, 1978).

48. Herendeen, R.A., "Affluence and Energy Demand", Mechanical Engineering, October 1974.

49. Swedish Secretariat for Future Studies, Energy in Transition, Bohuslaningens, 1977.

50. Jorgenson, N.O., Housing Finance for Low Income Groups, University of Nairobi, Kenya, 1977.

51. Reisman, A. and Malone, R., "Less Developed Countries Energy System Simulator. LDC-ESNS", BNL 50836, April, 1978.

52. Several such projections are available in the "Metropolitan Growth Strategy", (Reference D-1).

53. Unless changes occurred in the propensities to save or in an area of consumption not incorporated in the profile.

APPENDIX A
Nairobi and Mexico City: A Comparison

Geographically, Nairobi and Mexico City are very similar. Both are cities of high altitude with mild climates. Both are the economic centres of their countries. Both are growing rapidly and have high migration rates. Both are situated in LDC's. At the same time, Mexico City's population is larger than Nairobi's by more than a factor of ten. In addition, there are many social and economic differences and very different energy resource situations.

In comparing the household energy use profiles it is difficult to distinguish between the differences brought about by socio-economic factors and those brought about by Mexico City's larger size. It is possible, however, to see if the different trends in Mexico City are consistent with one's expectations for larger, more developed urban areas. The energy use profile for Mexico City is given in Figure A-1. Since differences in the income breakdowns and inadequacies in the data preclude a detailed sectoral analysis of the differences in energy use patterns, we have attempted to summarize the results in two variables for each activity sector:

i. Average per Household Primary Energy Demand
ii. Income Elasticity of Energy Demand*

The resulting estimates for these two variables are given in Table A-1. Looking first at the income elasticities, they appear similar between the cities in all sectors except direct residential uses. The transportation and construction income elasticities are consistently high, and in both cities the food elasticities are substantially lower. The variation of the residential elasticities between .5 in Mexico and .7 in Nairobi is larger than one might expect, though in both cases it falls below transportation and construction and above food. Some of the difference in residential elasticities appears to be due to the higher levels of energy use among the low income households in Mexico City, but for the most part, the affect is caused by higher estimates of fuel consumption at upper income levels in Nairobi.

Table A-1

Sector	Variable	Mexico City	Nairobi
Residential	F	33	36
	e	.49	.76
Transportation	F	66	13
	e	1.1	1.0
Food	F	26	17
	e	.72	.72
Construction	F	17	13
	e	.89	1.0
Total	F	142	79

Sources and Notes:

F: Fuel demand in primary energy ($Jx10^9$) per household.

e: Income elasticity of energy demand over 5 income groups. Services have been omitted from this comparison due to uncertainty in estimates.

* For each activity sector income elasticities have been calculated from the equation $e = \frac{F_5 - F_1/F_5 + F_1}{I_5 - I_1/I_5 + I_1}$, where F_i is the fuel use per household in income group, and I_i is the average income. The income ranges are similar in each city making the elasticities comparable, but it is the variation between the sectors within each city which is of principal importance.

The average levels of fuel consumption displays widely divergent patterns but appears consistent with expectations. The higher average levels of fuel consumption in the food and construction sectors for Mexico City are consistent with the higher average income level. The higher average level of fuel consumption in direct residential uses in Nairobi appears to be the result of less efficient energy use caused predominantly by the high levels of electricity consumption* (the reverse affect is present comparing Basic Energy Demands). The immense difference in the fuel consumption of the transportation sector requires some elaboration. The average trip rates per household 6.8 trips/day in Nairobi and 8.5 trips/day in Mexico City. This 25% difference corresponds roughly the difference which would be expected in view of the higher average income level in Mexico City and is evidently not the principle cause for the wide divergence in fuel consumption. Nor is the more extensive use of the automobile surprising or particularly significant. The congestion and large average car size in Mexico City leads to lower fuel efficiencies, but once again this could only account for a small proportion of the divergence. The principle cause seems to lie in the trip lengths. Transportation planners have long accepted the relationship between city size and trip lengths, though its functional form is highly dependent on more than three times their current length by 2000. It is evident, therefore, that transportation fuel demand determination is largely exogenous to the income/energy use relationship.

In addition to the aggregates discussed above we have included Table A2 comparing the fuel mix of residential activities between the two cities. The differences are large enough to warrant comment even in the absence of strictly equivalent income classifications. A shift away from wood and charcoal towards oil based fuels and eventually towards a high proportion of electricity consumption is evident in both cities, but the details of the shift are very different. Wood and charcoal usage become insignificant in Mexico City by the low middle income group and only account for 28% of the fuel consumption even at the lowest income level. In Nairobi, wood and charcoal are the most important fuels until the middle income group and remain significant up to the highest income group. The switch to electricity at upper income levels is, however, much more complete in Nairobi. Unfortunately, without further information it is difficult to determine the significance of these differences.

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* Since hydro power and other non oil based fuels are expected to account for over 85% of the electricity generation by 1984 this "inefficiency" does not reflect an undesirable situation.

Fig. A1

M.A.M.C. Per Household Energy Consumption by End Use and Fuel Type.

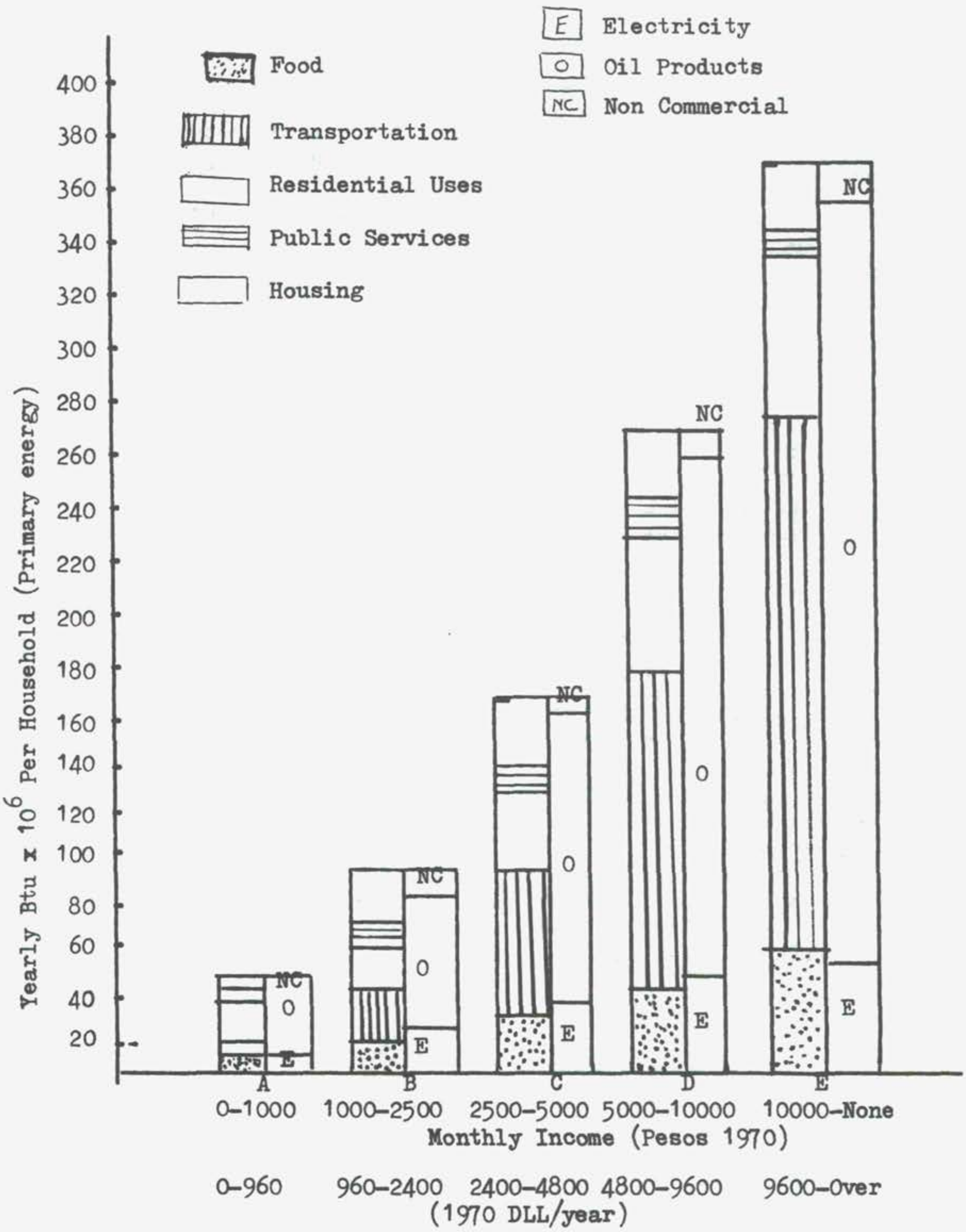

Table A-2. Fuel Mix for Direct Residential Use.

	Income Group									
	Low		Lower Middle		Middle		Upper Middle		High	
Fuel Form	N (23)	MC (17)	N (36)	MC (44)	N (23)	MC (22)	N (13)	MC (11)	N (5)	MC (7)
Wood and charcoal	67	28	67	0	20	0	10	0	5	0
Oil based	33	55	24	63	26	53	12	49	1	43
Electricity	0	17	9	37	54	47	78	51	95	57
	100	100	100	100	100	100	100	100	101	100

( ): approximate % of households

N : Nairobi

MC : Mexico City

APPENDIX B
Fuel Equivalencies

Fuel Type	Quantity	10^9 Joules
Wood (30% void)		
Green wood (50% moisture)	1 metric ton	9.28
Air dry	1 metric ton	11.61-13.93
Moisture and resin free	1 metric ton	18.57
Resins[4]	1 metric ton	37.14
Charcoal[4]	1 metric ton	27.39-31.1
Biogas[4]	1 metric ton	11.0
Dung[2]	1 metric ton	11.0-25.5
Coal[1]		
Anthracite	1 metric ton	32.49-34.82
Coke	1 metric ton	29.24-32.5
Bituminous	1 metric ton	25.1-31.4
Lignite	1 metric ton	11.2-18.0
Gas[4,3]		
Natural gas (wet)	1 cubic metre	.0357-.0487
Natural gas (dry)	1 cubic meter	.0367
Methane (CH_4)	1 cubic metre	.3613
Coke gas	1 cubic metre	.0184
Synthetic gas	1 cubic metre	.00367-.0367
Hydrogen	1 cubic metre	.01102
Blast furnace gas	1 cubic metre	.00367
Petroleum products		
Crude oil	1 barrel	6.120
LP gas (propane/butane)	1 barrel	4.23
Gasoline	1 barrel	5.54
Kerosene	1 barrel	5.98
Aviation fuels	1 barrel	5.54
Distillate (diesel, gas oil, heating oil, number 2 oil)	1 barrel	6.145

Residual (heavy oil, bunkerfuel, oil numbers 5 and 6)	1 barrel	6.63
Barrel of oil equivalent (B.O.E.)		6.120

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[1] coal fuel-energy equivalencies are taken from U.S. Bureau of Mines and Brookhaven report (BNL 50483).

[2] Dung value is taken from Earl, D.E. in Chapter 3, p.22 of Forest Energy and Economic Development, Clarendon, Oxford, 1975.

[3] Fuel-energy equivalencies for gases are taken at the pressure and temperature corresponding to a density for air of 1.32 kilogram per cubic metre and corresponding to the following fuel densities:

Gas	Density (kilogram/cubic metre)
Natural gas (wet)	.790 - 1.05
Natural gas (dry)	.790
Coke gas	.790
Blast furnace gas	.790
Synthetic gas	.790
Hydrogen	.092
Methane	.724

[4] Fuel-energy equivalencies for gas, petroleum and non-commercial fuels are taken from BNL report 50483.

APPENDIX C

District: No. of floors in building:

Ethnic Group ____________

I. "Do you use electricity" Y ☐ N ☐ N go to II

"Do you have?" Electric Bulbs Y ☐ N ☐ No.___Wattage Range

Record Player(s) Y ☐ N ☐/AC Radio(s) Y ☐ N ☐/Iron(s) Y ☐ N ☐

Heater(s) Y ☐ N ☐/Fan(s) Y ☐ N ☐/ TV Y ☐ N ☐/Refrigerator(s) Y N

Washer Y ☐ N ☐/ _____ Electric water heater(s) Y ☐ N ☐

Electric Cooker Y ☐ N ☐ If Y: "how many burners?" [1] [2] [3] [4]

"with oven" Y ☐ N ☐

"Do you have any other electric appliances?" Y ☐ N ☐ If Y "specify" ☐

"What is your average electric bill?" Tariff 1 ________ksh/month
Tariff 6 ________ksh/month

II. "Do you use charcoal?" [Y] [N] If N go to III

"Do you have ajjiko?" [Y] [N] If Y "how many?" 1 2

"Do you burn any charcoal outside the jiko?" [Y] [N]

"How much charcoal do you use?" ______ sacks/month *
tins/day
ksh/unit

III. "Do you use paraffin?" [Y] [N] If N go to IV.

"Do you have a paraffin lamp?" [Y] [N] If Y "how many?" ____

"Do you have a paraffin cooker?" [Y] [N] If Y: No. of burners ____

"Do you have any other paraffin devices?" [Y] [N]
If Y "specify" __________

"How much paraffin do you use?" _______ debes/month

"What price do you pay?" ____________ksh/debe

IV. "Do you use bottled gas?" [Y] [N] If N go to V.

"Do you have a gas water heater?" [Y] [N]

"Do you have a gas cooker?" [Y] [N] If Y: No. of
burners 1 [ ] 2 [ ] 3 [ ]

"Do you have any other gas devices?" [Y] [N] If Y:
"specify" _____________

"What size is the cylinder?" ______kg.

"How long does a gas cylinder last you?" ______ weeks

"How much do you pay for each cylinder?" _________ksh.

V. "Do you have a battery radio?" [Y] [N] If Y: "How many
batteries/month?" _________

VI. "Do you use wood?" [Y] [N] If Y: "How much do you pay?" ___ksh.

VII. Socio Economic: No. of Rooms ________/No. of persons in household ________

No. of adults (over 16) _____ No. of wage earners _______

Total income ______ksh/month* "Do you pay rent?" [Y] [N]
L/year

Occupations:

NOTES ON HOUSEHOLD SURVEY

The questionnaire illustrated lists the core household questioning procedure which was carried out by two of the authors of this study and Mr. P. Ngulu. A modified version with more emphasis on wood and less on electricity was carried out in the Mathare Valley by Mr. P. Ngulu and Mr. K. Mbok. Additional information which was collected but not recorded for all households is given in the notes below.

1. Validity of Data

The questionnaire was generally supplemented by direct observation and additional questions aimed at checking the validity of the data being recorded. The most common check for validity of the charcoal and kerosene consumption information included a question regarding the time and quantity of the last purchase combined with an observation of the quantity of fuel remaining. In the few cases where inconsistencies were apparent the estimates were adjusted on the spot with the participation of the interviewees. Income information was checked for consistency with the occupations of the workers. Unfortunately, the wide range of possible incomes within each occupation limited this to a gross check and adjustments were only made in one case. Electricity information was not checked explicitly but was supplemented by the sampling from the electric power company (212 households). Appliances were observed directly.

2. Seasonal Variation

Monthly electricity data for sample households was checked over a one year period for seasonal variation. No statistically significant variation was observed.

3. Fuel Choice

The general consensus of low income households using both charcoal and kerosene was that they had a tendency to use kerosene for quick food preparation (breakfast and baby food) and charcoal for traditional dishes. A number of households (not using liquid gas)

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* Circle appropriate units.

expressed a preference for liquid gas due to its low fuel cost, but claimed they lacked the finances to purchase the stoves. An additional impediment to the use of liquid gas in the squatter settlements is the extreme fire hazard.

The noted awareness of relative fuel costs on the part of low income households is collaborated by an apparent change in fuel consumption patterns since 1974 as evidenced by the lower (approximately 40%) charcoal consumption and higher (approximately 150-200%) kerosene consumption recorded to the low income groups surveyed in 1974 by the Central Bureau of Statistics. The income groups are not directly commensurable but the differences are interesting nonetheless, and in view of the 200% increase in the price of kerosene over this period (versus 100% for charcoal), very reasonable.

RURAL ENERGY NEEDS AND ALTERNATIVE SOURCES

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BACKGROUND
RURAL DEVELOPMENT AND BASIC NEEDS

Although it is generally accepted that the bulk of the population in LDC like Kenya will have to live in the rural areas and the life there must be made attractive for them, few people appreciate the magnitude of the problem and the constraints imposed on it by the basic resources of land, labour and energy. Learning from other countries' experiences should be helpful. India, for example, has had a worsening landlessness for a century as shown below:

	1885	1975	2001
Landless: having land	2:11	9:11	18:11

Using the current rate of population increase, it is estimated that arable land per capita will decrease here in Kenya from present 0.8 ha to 0.3 by the year 2000. The way this land will be distributed will dictate the degree of landlessness.

Given the current low crop yield especially in the medium potential areas of Kenya where average farm size is about 3 - 4 ha, improvements would have to be very great to ensure sufficient income when the land size is reduced to less than half by the year 2000. Rather than hope for an exceptionally high land productivity, it is more realistic to assume that a substantial part of the population will have to be absorbed in rural industries and services in order to sustain a good supply of basic needs from rural sources and by the rural people. Thus a stable rural society may be achieved. Obviously some degree of export and import of goods and services from and to the rural areas will always exist.

However this process must be regulated and controlled to minimise the current technological dependency and virtual stagnation of indigenous technological development.

As a basic resource labour is not limiting in quantity but in quality and in its utilisation or lack of it. Labour bottlenecks are experienced in farms primarily because of the attendant drudgery that go with farm tasks and the low income generated from it. Better farm equipment and higher incomes relative to urban employment would change the whole situation. The education system as has been recognised by the National Committee for Education Objectives, has a lot to do with the rather disappointing manpower training for the rural areas.

Land and labour productivity will not occur unless energy input is available for agriculture, rural industries, transport and for domestic consumption.

As has been shown by Desai (1977) energy intensity of GDP[1] is higher in the less developed countries (LDCs) than in the developed countries (DCs). This is because LDCs have a high domestic consumption of energy of low concentration such as wood, dung and vegetable waste. Because of low direct cost, it is often wasted through inefficient cooking jikos.

In agricultural sector however productivity per unit energy input is substantially greater in the LDCs than in the DCs. This means that DCs except Japan have replaced labour by a lot of mechanical and chemical energy. This trend is illustrated in Figure 1.

In a way high energy input in agriculture has solved land problem in the United States. Over twenty-five years both the energy input and yield per acre of maize has trebled. (Pimentel et al 1973). This was done during the time of cheap fossil fuel and cannot be possibly repeated or even maintained. However with better choice of mechanisation and more exploitation of renewable energy sources good agricultural production can be maintained.

Rational choice of food production and consumption will also help to conserve the limited energy that is available. Beef production using grain and fodder is one very important factor that caused high energy consumption per dollar output in the DCs.

Ideally what we want is a self-reliant rural society whereby the available land and energy is organised by the rural manpower to (at the very least) produce the basic needs at socially acceptable level. Whether other factors such as population growth and pollution will in future become the major constraining factors or not, is well worth finding out.

ESTIMATES OF RURAL ENERGY NEEDS

Although no data is available for a complete and reliable assessment of rural energy consumption, it is felt necessary to make a rough estimate of this energy need in order to appreciate the seriousness of the problem. The estimates given in Table 1 were developed using the limited information available from statistical abstracts published by the Central Bureau of Statistics and also drawing on information on rural energy consumption in India and elsewhere.

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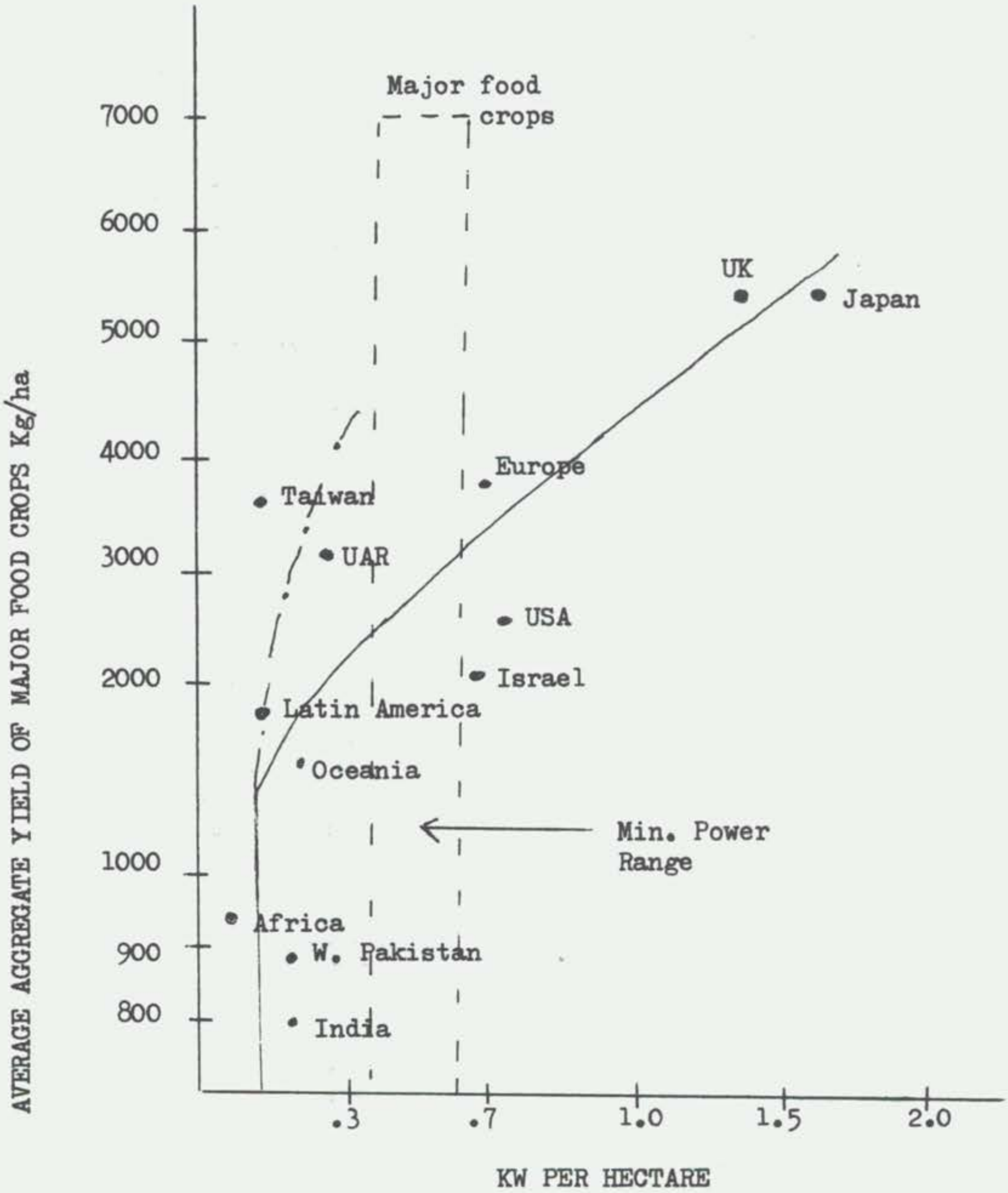
[1]Energy intensity of GDP = Energy Consumption per dollar GDP



1. Cereals, pulses, oil seeds, sugar crops, raw sugar, potatoes, cassava, onions, tomatoes.

2. Excluding mainland China.

<u>Figure 1:</u> <u>Relationship between yield and power input</u>

Source: Verma S A Agricultural Mechanisation in Asia 1972.

Table 1: Estimated current energy consumption and estimated demand in the year 2000 assuming no drastic measures are taken

Source of Energy	ENERGY USED IN KCAL X 10^{10}								% Total
	Agriculture		Domestic		Rural Industries and transport		Total		
	Current	2000	Current	2000	Current	2000	Current	2000	
Human	58	118	38	76	10	20	106	212	3.2
Animal	13.6				3.4		17		.5
Kerosine			59.6	119			59.6	119	1.8
Firewood			3100				3100	6200	92.9
Fertilizer	54.19	108.38					54.19	108.38	1.6
Total	125.79	226.38	3198	195	13.4	20	3336.8	6639.38	
% Total	3.8		95.8		.4		100		100

The principle sources of energy currently being used in the rural areas are as follows :

human (3.1%), animal (0.5%), firewood (91.8%), kerosine (3.0%) and chemical fertilizer (1.6%). (See table 1). The consumption is disaggregated into three major scetors namely : agriculture (3.7%), domestic (95.9%), and rural industrialisation and transportation (0.4%). The energy consumed in rural transportation using engine powered vehicles is not included in this calculation but it is considered to be low. Also not included is the mechanical energy in agriculture which is also considered low. Only about 3.5% of the smallholder agricultural land is currently being cultivated by tractor.

Animate Energy

The importance of animate (human and animal) energy in food and biomass (wood, vegetable and animal waste) energy production is often lost sight of in rural energy considerations. People talk about afforestation programmes to supply wood and to improve environmental quality and of biogas-slurry systems to fully utilise the farm wastes without thinking seriously about the energy input necessary for the agricultural activity behind these programmes. If mechanical energy is assumed or even implied the problems in replacing the currently available animate energy are not well appreciated. Very well documented mechanisation problems are often seen quite apart from energy problems. We feel that mechanisation and energy problems are highly interrelated and their considerations should be integrated. In this way the problems of energy production, conversions and use can be identified. Figure 1 shows how crop production is related with power available on the farm. The take-off point is the point at which human and animal energy is replaced by mechanical power as is the case in Europe, USA, Israel and Japan. More labour-intensive methods utilising inputs such as irrigation and improved seed and chemical fertilizer have achieved high output in Taiwan and UAR without high installed power per ha.

Human Energy

Over 84% of all the land cultivated by small holders is done by hand tools. Labour is supplied as demanded by the seasonal requirements usually characterised by severe bottlenecks.

The labour input in Kenyan households by province is given below:

Manhours (family and hired) per household per year

Province:	Eastern	Nyanza	Western	Coast	Central	R. Valley
Manhours/ household/ year	3710	3070	2560	3285	3105	3415

Average : 3191

Source: IRS Central Bureau of Statistics

It is estimated that on the average the energy output per manhour equals 225 Kcals measured by oxygen consumption during the working hours.

It is also estimated that the total farming population is 10,340,000 constituting 1.48 million rural households each having approx. 7 persons. The total human energy consumed by this population per year equals :

$$3191 \frac{\text{manhours}}{\text{household}} \times 1.48 \times 10^{6} \text{ Households} \times 225 \frac{\text{Kcal}}{\text{manhr}}$$

$$= 106 \times 10^{10} \text{Kcals}$$

Using Indian experience as reported by Revelle (1976) 55 per cent of this energy is probably used in agriculture, 36% in domestic activities and 9% on rural industries and transport. The corresponding amounts are shown in Table 1.

Animal Energy

Animal draft power is not widespread in Kenya as it is in other Asian and African countries. Some estimates by the Ministry of Agriculture show that there are approx. 60,000 draft animals in Kenya being used mostly in the medium potential areas in lower Embu, Meru, Kirinyagah and in most of Machakos and Kitui Districts. Oxen are also used widely in Gungoma, Busia, Kakamega, Kisii, Kericho and Kisumu Districts. The amount of land worked by oxen is also estimated at 150,000 ha or approx. 12.5% of all the land cultivated by small holders. Although the scope for more utilisation of animal draft power especially in the medium potential areas is still great since livestock is and will continue to be a part of farming, it is severely limited by lack of appropriate equipment innovations an d training for the oxen as well as the farmers.

Before land pressure is sufficiently high to push the animals out of the land in Africa, and experience in Asia shows that this could take a very long time, efforts must be mounted to improve their use and efficiency. This should be done in two fronts: (1) the animal power should be improved through better breeding, training and maintenance of animals, (2) equipment should be designed to optimise the use of this power. Long experience in Asia, West Africa and what is left of the European experience should be used.

Recent efforts in Kenya are of great interest. The ox-training unit of the Arch-Diocese of Maseno is one very foresighted development by a church organisation. This work has been extended to other areas through worthy efforts of the National Christian Council of Kenya (NCCK). These efforts have no doubt acted as a catalyst in the country. The Ministry of Agriculture has now mounted a big project to precisely look at farm equipment for small farmers including ox-equipment. We believe that credit will now be available not only for the purchase of ox-drawn equipment but for their hire as well.

In addition to these efforts, the University of Nairobi has now included hand tools and ox-equipment in the agricultural and agricultural engineering curricula. A research project has also been mounted to look into the tillage and equipment systems using the oxen and other sources of power.

Animal energy consumption may be estimated in several ways. For instance the energy consumed can be considered as the energy contained in the feed eaten less the energy in the dung and milk produced. Alternatively it may be considered like humans' manual workers to be about 43 per cent of the food eaten. The second method suggested by Revelle is used here. In this case the energy input into work by animal is estimated to be about 23,000 Kcals per hour. It is also estimated that a full occupied oxen can work 1200 hours per year giving a total of

$$23{,}000\ \frac{\text{Kcals}}{\text{hr}} \times 12000\ \frac{\text{hrs}}{\text{year}} \times 60{,}000\ \text{oxen}\ \frac{\text{Kcals}}{\text{year}}$$

or

$$17 \times 10^{10}\ \text{Kcals/Year}$$

We have assumed arbitrarily that 20% of this energy is consumed in rural transport. The corresponding quantities are given in Table 1.

Firewood

Firewood is the major source of energy for the domestic consumption. Few rural household use charcoal which is mainly used in the urban centres. No data is available for firewood consumption either in form of cut trees or vegetable waste. For our purpose we have considered two estimates. One estimate is simply taking the per capita energy consumed by Indian rural families. This usually includes charcoal, vegetable waste and cow dung. Using this estimate the total energy consumed by the 10.34 million rural Kenyans is 14.9×10^{12}. Due to more severe fuel scarcity and hence higher efficiency of fuel burning in India this figure is likely to be an underestimate. The second estimate is taken from UN 1975 Year Book of National Accounts Statistics, 1974 (Vol. I and II). From this source it is given that the annual firewood consumption in Kenya is 31×10^{12} Kcals. It is assumed here that most of this energy was consumed in the rural areas. This is slightly more than twice the Indian per capita consumption. The second figure is considered more realistic for Kenya where firewood is relatively cheap and fuel economy very poor.

Kerosine

Kerosine is the main source of light for household homes. No information is available on the consumption of this fuel in Kenyan rural areas. Indian per capita consumption figures are therefore used for the estimate given in Table 1.

Chemical fertilizer

Many rural farms do not apply much chemical and if they do, less than optimum amount is applied. Usually fertilizer is used for the hybrid seed planted. IRS of Central Bureau of Statistics have reported that farmers spend on the average shs.42.00 on chemical fertilizer. Taking a cost of approximated shs.100.00 per 50 kg bag of nitrogenous fertilizer it is estimated that farmers use about 21 kg of fertilizer per household. The total amount used by 1.48 million households equals:

$$21 \times 1.48 \times 10^{6} = 31.1 \times 10^{3}\ \text{tons}$$

The corresponding amount of fuel that would be necessary to produce this fertilizer is 48,000 tons. At 11.4×10^6 Kcals per ton the energy required to produce this fertilizer equals :

$$48{,}000 \times 11.4 \times 10^6 = 10^{10} \text{ Kcals}$$

ENERGY CONSUMPTION TRENDS ASSUMING NO DRASTIC MEASURES ARE TAKEN

Most of the petrolium and coal imported in this country is used in urban centres. However a small quantity usually of kerosine and chemical fertilizer filter into the rural areas. The bulk of energy consumed in the rural areas comes from usually non-commercial sources such as firewood. Current domestic energy consumption amounting to 95.8% of the total energy consumption is alarming in the face of current deforestation and its consequent soil erosion, desertification and environmental pollution. In all probability the increase in domestic fuel consumption will be directly proportional to rural population increase unless special measures are taken to increase fuel consumption efficiency by using better designed jikos. Also, unless drastic measures are taken NOW to develop alternative sources to replace firewood currently supplying 93.0% of all rural energy, deforestation, burning of vegetable waste and eventually burning of cow dung will be inevitable. The result will be impoverished rural environment and serious social problems.

Although low in energy terms, animate energy (human and animal) now constituting 3.7% of all the energy consumption, has uniqueness and intrinsic value in agriculture. This is because of its management component as well as its operational skill. For this reason it cannot be replaced easily. Efforts to use large tractors in small-holder agriculture in Kenya in the last fourteen years have virtually failed. Proper choice of power and equipment must be made for specific cropping systems in various agri-ecological areas. This must be harmoniously combined with available labour, land and energy resources in order to ensure sustained productivity without disruptive effects such as unemployment, technology dependency or resource degradation or environmental pollution.

The petroleum source of energy is subject to depletion and high cost. Professor Githinji estimated that while the price may go up 400% by the year 2000, the oil tap could very well be turned off by the year 2010. This is probably a very optimistic view as far as the rural areas are concerned and oil could be unavailable much earlier. Like firewood consumption the increase in consumption of kerosine and fertilizer will be directly proportional to population increase expected to double by the year 2000, assuming that current birth control measures will not be effective in the rural areas.

In short the problem of energy for rural Kenya may be summarised as follows :

While as land resource conservation and elimination of environmental pollution demand that the current energy consumption from firewood be either replaced by another source or be met from vigorous afforestation programmes, there does not exist easy solutions to meet either of the two alternatives. Afforestation programmes are already experiencing difficulties because of land demand for agriculture. Any possible afforestation programme will be unlikely to meet charcoal requirements for urban poor and have surplus wood for construction in both rural and urban areas let alone firewood for the rural areas.

Kabagambe estimated that the total charcoal requirements by 1980 mainly for urban and other uses to be 1.68 million tons (.3 million tons for rural). This would require .74 million hectares; an increase of 43% on the current forest area estimated at 1.7 million hectares. It would be very difficult to achieve this amount of afforestation, given the current land problems. We can therefore assume that any amount of afforestation will only meet urban requirements.

Other alternatives such as biogas and pyrolysis which are discussed below, have both technological as well as socio-economic problems yet to be resolved. They depend on a sustainable high agricultural productivity requiring land, plant nutrients and mechanical power (to supplement currently available animate energy). However if definite measures are taken now to exploit all the options available among renewable energy sources including biomass (biogas, pyrolysis, alcohols), wind, solar and small hydro, real possibilities exist as we shall show.

POSSIBLE ALTERNATIVE SOURCES OF ENERGY FOR RURAL AREAS

Biomass energy

As mentioned above it is important to integrate energy production, conversion and use. Biomass energy systems depend on the efficiency of cropping systems in tapping the direct solar energy through photosynthesis. Table 2 shows the potential for agricultural land to produce biomass. For annual crops in the tropics the potential of 30 tons per ha depends on very intensive agriculture requiring inputs such as fertilizer, mechanisation, labour and management. This is not easy to achieve and the primary problem in rural development is to achieve agricultural output. The biomass energy conversation systems shown in Figure 2 largely depend on production potential of the land. We have considered three major processes that may be considered for rural development namely pyrolysis, biogas-slurry system and power alcohol.

Table 2 : Average to good annual yields of dry matter

	t/ha/ year	g/m^2/ day	Photosynthetic efficiency (% of total radiation)
Tropical			
Napier grass	88	24	1.6
sugar cane	66	18	1.2
reedswamp	59	16	1.1
annual crops	30	-	-
perennial crops	75-80	-	-
rain forest	35-50	-	-
Temperate (Europe)			
perennial crops	29	8	1.0
annual crops	22	6	0.8
grassland	22	6	0.8
evergreen forest	22	6	0.8
deciduous forest	15	4	0.6
savanna	11	3	-
Desert	1	0.3	0.02

Pyrolysis

This is the process whereby wood is reduced to charcoal, oil and gas under restricted ventilation. Although charcoal-making has been practised for a long time it is observed that the traditional method is inefficient and wasteful since no oil or gas is recovered and the energy content in the charcoal is usually less than 15% of input energy. Better designs of kilns would facilitate production of higher quality charcoal even if oil and gas cannot be collected.

In recognition of the fact that people have used charcoal for a long time and this has partly contributed to deforestation, pyrolysis plants especially at community level would certainly reduce the rate of deforestation. This should be supplemented by better designs of cooking stoves to increase efficiency and further reduce the demand for charcoal.

The technology is well developed and can be applied at community level. Systems that would recirculate gas for heating and recover oil for use for light or fuel, should be encouraged.

Complementality and substitutability between pyrolysis and biogas systems should be carefully studied. For instance the fibrous dry vegetable waste with low fertilizer content might be more appropriate for pyrolysis while the green or wet vegetable material with high

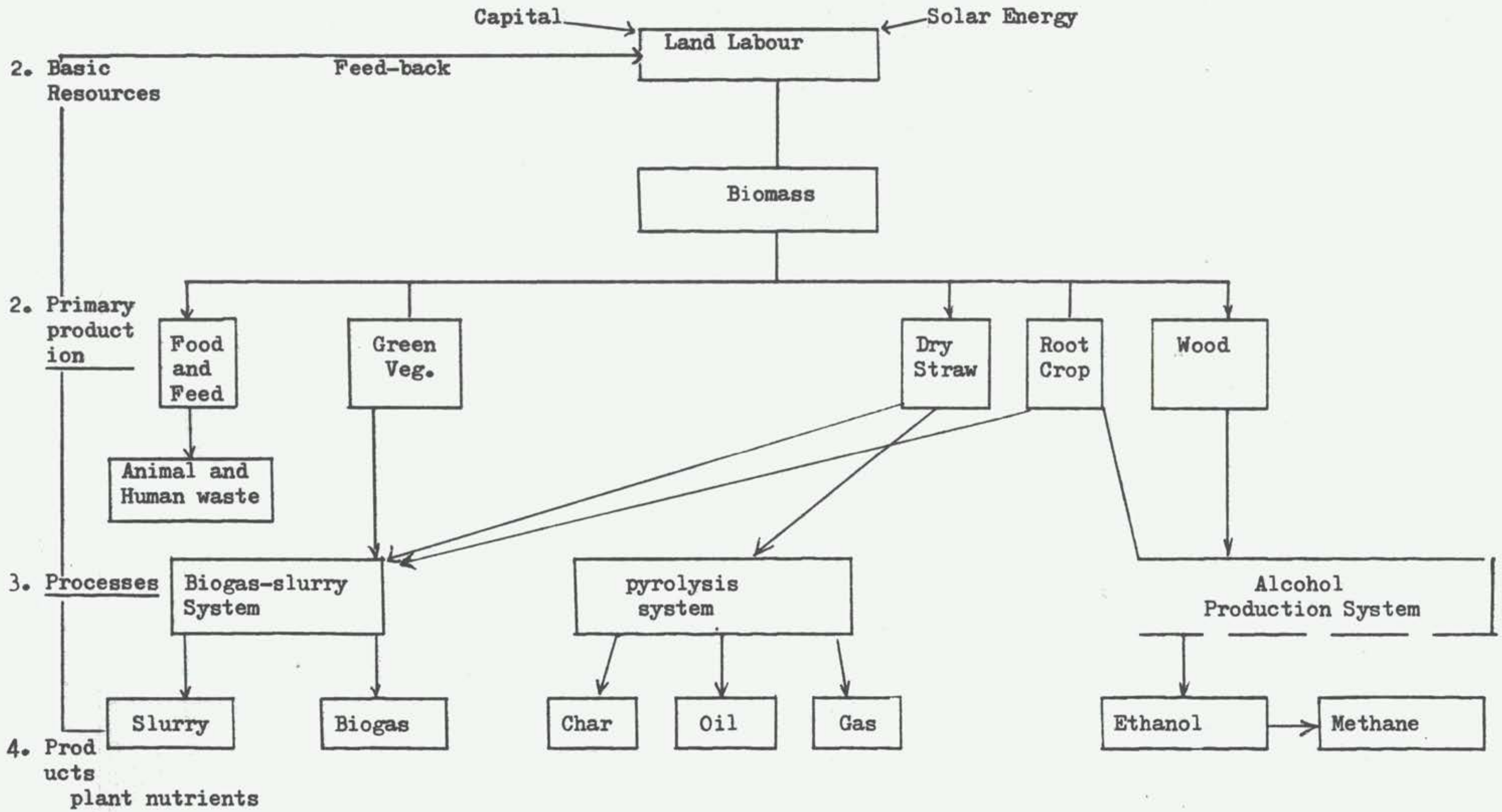


Figure 2: The conceptual framework of the alternative biomass energy production systems

nitrogen content might be more suitable for biogas systems. The management problems are certainly different. The biogas system often demands daily collection of messy and even smelly cow dung, human excreta and household waste. The pyrolysis system on the other hand involves dry products which can be accumulated and dealt with over a short period of time. The process control however is much more complex. In the case of household use, charcoal is widely adopted; biogas is not and would need an extension programme.

Biogas-slurry system

This system involves digestion of vegetable waste under anaerobic (no oxygen) conditions. Vegetable waste such as cattle dung, human excreta, farm waste is mixed with water to produce slurry which is converted into biogas (approx. 70% methane and 30% CO_2) and sludge containing plant nutrients and indigestable inorganic solids. The plants nutrients such as nitrogen, phosphorous, potassium an other trace elements are contained in the sludge and may be returned to the land. This system is therefore very acceptable to the environmentalists, conservationists as well as to the farmers.

The available technology which is substantial and well publicised, is still too expensive and does not render itself to widespread adoption. Less expensive individual units or community units merit priority attention. Community units are attractive in the sense that the very poor can be included in the system. Experience in India shows that after supplying cooking needs, there is sufficient surplus gas which can be used for electricity generation and mechanical power. This would ma ke electric lighting, central processing of farm crops, farm mechanisation and transport possible. In fact the problem of collection of vegetable waste and home delivery of compressed gas and sludge might be considerably reduced.

It was felt, however, that before widespread adoption is attempted, careful study of pilot plants is very essential. In particular it is important to study gas output of various material mixes, problems of collection of farm waste, distribution and use of the outputs namely: gas, electricity and plant nutrients. It is also important to assess the overall socio-economic benefits to the community as a whole.

Assuming that annual crops in small holder farming can yield approximately 20 tons of dry matter per year, 10 percent of which is consumed as human food, it is estimated that anearobic digestion of the balance of the vegetable waste from an average farm of 2.3 ha (1.2 ha cultivated, 1.1 grazed) would produce enough energy for domestic, agricultural and rural industrial use by the year 2000. This assumes 50% increase on the current average cultivated land estimated at .8 ha per family. It also assumes that although the population will increase, the total land held by small holders will not change significantly from the present 1.48 million hectares. Current land scarcity would support this assumption.

One holding would produce 24 tons of dry matter from 1.2 ha of cultivated land. After subtracting 10% of food 21.6 tons of dry matter is available for digestion. To this must be added the cattle dung from estimated 3 livestock units per holding. At 1.1 kg total solids per livestock unit of 200 kg (Makhijan 1975) and assuming 75% collection of dung a total of 887 kg can be expected. The total energy recoverable in anaerobic digestion assuming 60% efficiency (Makhijan 1975) equals :

$$22487 \text{ kg dry matter} \times 3700 \text{ Kcal/kg} \times .6 = .50 \times 10^{8} \frac{\text{Kcal}}{\text{Holding}}$$

The potential production from 1.48 million holdings equals 7390×10^{10} Kcal.

This is more than the estimated total rural energy consumption in the year 2000 when the population will have doubled. Use of biogas instead of firewood for cooking would increase fuel efficiency from 9% to 40%. In this way the estimated demand of 62000×10^{10}Kcal for firewood would be replaced by 1550×10^{10} Kcal of biogas. The balance of $(7390 - 1550) \times 10^{10}$ or 5840×10^{10} Kcal will be available for agriculture (mechanisation, processing and irrigation), for rural industries and farm transport.

Alcohols

This process involves reduction of sugars and starches to ethanol through fermentation process. Ethanol is then destilled to produce pure alcohol which is used in the chemical industry as well as in motive power.

The need for distillation makes this process capital-intensive and too complex for small rural centres. It is also not efficient in terms of energy conservation because distillation consumes a lot of energy. It is felt that this system is not suitable for widespread application in rural areas. However where land is not a constraint and there is a need to replace petroleum by this equally concentrated energy especially for long distance motive power, extensive production of alcohol from root crops such as cassava can be justified as experience in Brazil has shown.

However, there is a need for R and D on small alcohol production units that could be installed in small rural centres.

Wind Power

The potential for wind power utilisation in Kenya exist in many parts of the country. In fact, there are many windmills especially in the large scale farming areas which were used before but are now replaced with diesel engines and mains electricity. With the increasing cost of diesel and electricity it will be well worth reviving windmill technology.

Unfortunately the windmills used in this country are of foreign design and manufacture especially from America and Australia. The unit cost tend to be too high for even the progressive small-holders in Kenya. Fortunately recent efforts in the Department of Mechanical Engineering of the University of Nairobi, by Dr. Hilton indicate that careful design selection and use of local materials could reduce cost very considerably to approx. shs.4,000 per unit. However, this is still beyond many small-holder farmers.

Because of limited use of direct wind power (milling and water pumping only) and extra cost involved in electricity generation supply and storage, it would be difficult to justify individual family untis.

However large community units especially for water pumping and electricity generation are well worth considering as wind power potential is good.

Recent work in Australia, America, Europe and Argentina, among others, indicate renewed interest in wind mill technology and we can expect great advances in design economy, ease of construction and higher efficiency. Vertical axis type of windmills is one such development that is likely to make an important break-through.

Solar Energy

Solar Heaters

Solar water and space heating is well established. However the cost, and the fact that domestic water and space heating are not high priority needs in the tropical rural areas has restricted widespread use of this technology in these areas.

Solar Refrigeration

Technical possibilities exist but the technology is not commercially available. It is likely to be expensive. Central units to serve large communities like schools, hospitals in remote areas may be justified.

Solar Still and Desalination

The technology is old and simple. Salt production is particularly well adopted in less developed countries.

Solar crop drying

In simple form solar crop drying is old and universally adopted. This may take place in the field or in the household where the crop is spread out in thin layers.

In recent years however, solar drying means drying with solar heated air in protected surroundings. Special solar collectors consisting of glass covering and a blackened surface are used to increase the temperatures.

Where mechanical or electrical power is available solar driers may incorporate forced airflow. Addition of solar air heater to unheated air-drying system can shorten drying time by 50 - 75 per cent. The cost of solar drying is largely offset by the saving in cost of circulation fan as a consequence of the lower power requirement.

There is a need for research and development to improve the collector drier combination for specific crop drying requirements at low cost. This is particularly necessary in the rural areas of LDCs.

Power Generation

Solar power generation usually include collecting and/or concentrating incident solar energy - to produce steam or other vapour, which is then employed in engines of various types to generate electricity or mechanical power. The oldest such unit was a plant built in Egypt in 1913, which developed about 37 KW (50 hp).

Most of the research has been directed towards the use of reflecting surfaces to concentrate the solar energy onto a small receiver/boiler, which permits the development of much higher temperatures than is possible with flat-plate collectors.

The French designs based on the design by Girardier are being tried in Africa. A flat plate water heater supply hot water to a boiler in which propane is vaporised and from which this vapour is supplied to a reciprocating engine. Several installations of 1 to 3 KW are in service. Although the efficiency of 1% is low it could be substantially increased by design improvements. The unit costs are high but may compare well with similar diesel installations when running cost of maintenance and fuel supply in remote areas is taken into account.

Photovoltaic devices

Solar cells, usually in the form of thin films or wafers, are semi-conductor devices that convert 3 to 30 per cent of incident solar energy in DC electricity, with efficiencies depending on illumination - spectrum intensity, solar cell design and materials and temperature. A solar cell behaves like a low-voltage (.5 volt) battery whose charge is continuously replenished at a rate proportional to incident illumination.

The development for photovoltaic devices has up to now been largely motivated by space craft uses but right from 1955 when the silicon cell was invented there have been many terrestial applications such as to house lighting, navigational and warning lights, radio, microwave and television relay stations, weather monitoring stations, remote-television sets, forest management, etc. Most commercial units are restricted to low power of up to 1 kW.

Alth ough simple enough for rural application, the commercially available photovoltaic devices are far too expensive and can only be justified for special application in remote areas where conventional power sources are not available.

Current R and D activities however indicate that the cost can be reduced substantially. In India it has been estimated that in ten years time it may be cheaper to provide rural electricity for domestic and agricultural uses from photovoltaic cells cheaper than from conventional sources.

Small-hydro

Direct water power has been used locally for many years especially for grinding. Simple designs using local materials were made. However the technology has long been discarded and like wind mills, replaced with diesel engines.

Hydro-electricity generation is well established in Kenya. In 1976 over 50% of installed capacity was from hydro sources. It's share of electricity generation will increase in the near future. However for some reasons, most probably commercial, small-hydro electricity has not received much attention. It only exists in isolated places such as ranches and estates. This is inspite of the fact that it might be even cheaper as has been demonstrated by Brooke Bond. They have 2 stations at Kerenga and Jamji developing about 1440 kva on river Kemugu and Ketho. Their information indicate that their generation cost was not more than 13 cents against 31 cents that they would otherwise have to pay EAP and L.

Like wind and solar hydro energy has high capital cost and the smallest unit possible is far beyond the means of the individual small-holder. The alternative is to consider community units primarily for rural electricity supply in areas where the potential exist.

RURAL ENERGY POLICY

As shown in this paper the problem of rural energy supply can be identified. Although environment conservationist has sounded the alarm we must not underestimate the gravity of the problem. The rural people do not appear to appreciate the seriousness of the problem most probably because of short-sightedness. Their co-operati on in solving the problem cannot be taken for granted. The policy makers on the other hand need hard facts and concrete programme proposals to solve the problem before they can fully commit themselves.

In addition, we have in this country inequality problem. The urban medium and high income group wants gasoline, natural gas and mains electricity and will pay any price for these essential commodities. The urban poor on the other hand wants charcoal at a reasonable price. The demands of the urban community of about 10% total population and earning 10 - 20 times more income than their rural counterpart, has resulted in huge investments in hydro-electricity in the Tana, the Mombasa oil pipe line and in the E.A. Oil Refineries. There are not comparable efforts to meet the needs of the rural areas. The big question is whether we have reasonable basis to expect a significant change of policy that will result in a change in investment priorities. Can we expect a policy that will give emphasis to biogas-slurry, wind, solar or small-hydro? Although there is general awareness of the need to develop the rural areas as reflected in the current development plan (1978-1983), we should not overlook the fact that conflicts of interest exist which will make change of policy politically very difficult. However the challenge must be taken by those who can foresee the serious consequences of not solving the problem.

It has for instance been suggested that petroleum could be replaced with locally produced power alcohol from cassava or sugarcane. The immediate questions are: who will use most of this power alcohol? Where will land and other resources necessary for its production come from? What are the alternative uses for these resources especially in the rural areas where they exist? What are the socio-political implications?

If the political will exist, then there is a whole body of questions as follows :

- WHAT technology is to be used, embodied in WHAT type of production?
- HOW is that technology to be brought into use?

- FOR WHOM is that technology to be used?
- WHEN is that technology to be used in those ways and for those purposes and for those people?

Areas of decision making

Different but inter-related areas of decision making include :

a) decisions about which alternative, available technical systems to use - for what, when and for whom?

b) decisions about which directions to pursue in local R and D efforts. (This is not so much concerned about which R and D projects to select, but about which strategies of R and D to pursue).

c) decisions about how much of which foreign rather than local 'technology' to use when.

d) decisions about which local technological capabilities to develop when, for what and how

e) decisions about how best to link R and D to application and the use of techniques.

REFERENCES

Barnett, A; Pyle, L; Subramanian, S.K (1978). Biogas Technology in the Third World, IDRC Ottawa Ont. Canada.

Central Bureau of Statistics. Integrated Rural Surveys for 1974/75.

Chlala, H.G (1972). The Present Situation and Future Prospects of Charcoal Production and Consumption in Kenya. Industrial Survey and Promotion Centre, Ministry of Commerce and Industry.

Desai, A 91977). Development and Energy Consumption. Science Policy Research Unit, University of Sussex, UK.

Githinji, P.M (1978). Kenya's Energy Needs, Possible Supplies and Impacts on the Environment Department of Mechanical Engineering , University of Nairobi.

Industrial Survey and Promotion Centre (1978). Energy for Rural Development.

Kabagambe, D.M (1976). Aspects of Resource Conservation. The Role of Charcoal Industry in Kenya. Institute for Development Studies Working Paper No. 271, University of Nairobi.

King, R.P (1978). Development of Biogas-Slurry Plants and Systems in Kenya. Department of Agricultural Engineering, University of Nairobi.

Makhijani, A (1975). Energy and Agriculture in the Third World. Ballinger Publishing Company, Cambridge Mass, USA.

Muthee, A (1978). The Role of Biogas in the Rural Energy Package, 'Some Limitati ons and Possibilities' Paper presented at the Biogas Seminar held at Egerton College September 6 - 8, 1978.

Moulick, T.K et al. (1978). Biogas Systems in India. A Socio-Economic Evaluation. Indian Institute of Management.

National Academy of Sciences (1977). Methane Generation for Human, Animal and Agricultural Wastes. Washington DC, USA.

National Academy of Sciences (1976). Energy for Rural Development Washington DC, USA.

Parikh, K. Energy, Second India Studies.

Revelle, R (1976). Energy Use in Rural India. Science Vol. 192.

Uhart, E (1975). Charcoal Development in Kenya, United Nations Economic Commission for Africa. Addis Ababa.

BIO-ENERGY FOR KENYA: SOME TECHNICAL POSSIBILITIES

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SUMMARY

Bio-energy can meet the economic needs of Kenya, like those of many other developing countries, insofar as Kenya can little afford to import ever-growing amounts of fossil fuels at ever-growing prices. At the same time, bio-energy can utilise the natural resource that Kenya possesses in abundance, i.e. year-round warmth and sunlight. Bio-energy presents a labour-intensive set of technologies and labour costs in Kenya are generally low: a highly mechanised biomass energy plantation can generate an estimated 25,000-30,000 job years per 10^{15}BTU output of primary material, while eucalyptus plantations in Kenya and Tanzania, planted with hand tools, could produce 1.2 million job years per 10^{15}BTU output; from a yield of only 14 tons of material per hectare (half the yield that is generally feasible) (Poole, 1977).

Thus, bio-energy seems a "natural" for developing countries of the tropics. In fact, both immediate needs and ultimate potential appear to support development of bio-energy far more in developing countries than in developed countries— and it is doubtful if the same can be said of any other advanced energy system, including other forms of solar energy and geothermal and nuclear power. It is not too much to assert that many developing countries may enter the solar era before most developed countries.

INTRODUCTION

In the wake of steep price rises for petroleum in the last few years, much attention is being directed toward new sources of fuels and energy. This is especially the case in developing countries that do not have fossil fuel deposits of their own. Among prime candidates for these new sources is plant biomass, viz. vegetable matter that can be converted, through pyrolysis, hydrolysis, anaerobic digestion and other techniques, into liquid, solid and gaseous fuels.

Green plants capture the energy of sunlight and convert it via photosynthesis into food and fuel. Dry plant matter has an energy content of about 4 kilocalories per gram, or about 15 million BTUs per ton, roughly equivalent to 60 percent of the energy content of bituminous coal. Each day the process of photosynthesis is believed to store 17 times as much energy in plant matter as is presently consumed world-wide; or, to put it another way, the amount of solar energy falling on the earth's surface in just 10 days is equivalent to all fossil fuel reserves on earth. It was photosynthesis that originally gave rise to startpoint materials for geologic formation of oil, natural gas and coal. Now that man has developed technology to cut out the one third of a billion years that have transformed ancient green plants into petroleum and other fossil fuels, he can harvest the stored solar energy of present-day plants. In short, green plants, with their photosynthesising capacity, offer man a potentially efficient means to exploit solar energy. (For some recent literature on energy derivable from plant biomass, see Alich and Inman, 1974; Bassham, 1976; Bente, 1978; Brown, 1978; Calvin, 1976, 1977 and 1978; Hayes, 1977; Inman et al., 1977; Myers, 1979a and b; Pollard, 1976; Poole, 1977; and Williams, 1975).

A basic problem arises. To generate "bio-energy", a large amount of plant biomass is required in one place at one time. This paper proposes that much potential for growing plant biomass in sufficient quantities lies with developing countries of tropical zones, through exploitation of their most plentiful natural resources, sunlight. The paper looks at five options that could fit Kenya's needs: (i) agricultural and forestry residues; (ii) fast-growing tree plantations; (iii) fast-growing annual crops, notably sugarcane and cassava (iv) hydrocarbon trees; and (v) aquatic biomass systems. Some of these options will be more suitable than others. For example, fast-growing tree plantations and fast-growing annual crops may be economically difficult to establish in Kenya, insofar as only around 10 percent of national territory receives sufficient rainfall, and hence is at a premium for conventional agriculture. However, other possibilities may prove appropriate for drier areas, and for water bodies including the Indian Ocean seaboard.

Suppose the economic costs of producing biomass and converting it into fuels turn out to be competitive with other sources of energy. This would present a major prospect for generating energy on a renewable basis. The fuels would be of good quality: the sulphur content of plant matter is generally below 0.1 percent, compared to an average of about 2.5 percent for coal, while the ash content of terrestrial plants is typically 2-5 percent, compared with an average of about 14 percent for coal. Plant biomass is as easily burned or gassified as coal, though sometimes not so easily handled. Biomass-derived energy would be associated with few of the environmental draw-backs that accompany large-scale use of coal, oil and nuclear energy.

Agricultural and forestry residues

Kenya's main agricultural and forestry areas are in the moist parts of the country. As elsewhere in the moist tropics, these areas feature exceptionally high rates of photosynthesis, with sunlight energy for plant growth some 60-90 percent higher than in temperate zones. A tropical moist forest can fix carbon at a rate of one kg. per sq.me. per year; tropical forests are reckoned to account for 29 percent of all net photosynthetic activity on earth, almost 6 times as much as by cultivated lands, even though they occupy only 7 percent of the earth's land surface (Whittaker and Likens, 1975). The most productive of all well-known plants is sugarcane, which, under best circumstances, can produce as much as 100 tons of biomass per hectare per year. A range of plant communities, both natural and man-established, produce 3-5 times more organic matter each year in the moist tropics than is the case for plants in temperate zones.

Much potential is available to generate fuels and Energy through pyrolysing residual material from agricultural and forestry activities in Kenya. (Pyrolysis amounts to heating vegetable matter in air-free containers, whereupon an oil, not unlike true petroleum, is released, with around 75 percent calorific value of ordinary oil, plus a mixture of gases and flaky char). As a measure of what may be feasible through this strategy to exploit biomass, a US AID-sponsored experimental project in Indonesia has conducted trial investigations with the 17 million tons of plant wastes that the country produces each year: preliminary results indicate that it would be economically worthwhile to pyrolyse these materials into 1.5 million tons of charcoal and 0.9 million tons of oil per year, with a marketplace value of over $48 million (Tatom et al., 1977).

Fast-growing tree plantations

There is a major prospect for generating bio-energy through fast-growing tree plantations (Bente, 1978; Myers, 1979a and b; Poole, 1977; Rose, 1977). Wood consists primarily of polysaccharides, which are convertible to sugar and then to alcohol. Or, as an alternative technique, wood can be converted to synthesis gas and then to methanol, another highly satisfactory motor fuel. Trees go on producing wood, which is a very dense form of biomass fuel, for years on end, and provide continuous live storage without loss. The energy harvest per unit of plantation land can be many times greater than that from a similar patch of land under annual crops (but see below). Through pyrolysis, one metric ton of tropical dry wood can yield 13½ litres of methanol, 36 litres of wood oil and light tar, 330 kgs. of charcoal, and 140 cu.ms. of gas, together with 25 litres of acetic acid, 11½ litres of creosote oil, 7½ litres of esters, and 33 kgs. of pitch (Earl, 1975). It is estimated that a 12,000-hectare plantation of fast-growing trees could generate energy equivalent to one million barrels of oil per year (Clifton and Tatom, 1976).

Among tree species utilised for plantations are hardwoods such as eucalyptus and gmelina, and softwoods such as pines and other conifers. Certain of these tree species can be persuaded to grow almost like mushrooms. A highly-fertilised eucalyptus seekling grows at least 30 cms. per month, and reaches 20 ms. in height and over 25 cms, in diameter at breast height after only an 8-year rotation (the length of time a tree takes to reach marketable size), whereupon the plantation produces commercial wood at rates of 30-50 cu.ms. per hectare per year (Hillis and Brown, 1978; Mariani et al., 1978). A particularly fast-growing pine, Pinus caribaea, reaches almost 30 ms. in height after only 12 years, whereupon it yields an aggregate of 300 cu.ms. per hectare (Johnson, 1976). Many tree species readily permit a 50,000-hectare plantation to produce 1 million cu.ms. of commercial wood per year. Of course, a major challenge for plantation forestry is to track down those tree species that best lend themselves, through genetic breeding, to rapid growth. Some species reveal a better photosynthetic performance than others, due to differences in pigmentation, in make-up of leaf tissue, and in bio-chemical variations in pathways of carbon dioxide absorption.

A tropical tree species with apparently outstanding potential is giant ipilipil (Leucaena leucocephala) (Benge and Curran, 1976; U.S. National Research Council, 1977). This tree can grow 4 ms. tall in 6 months, almost 10 ms. in 2 years, and over 15 ms. in 6 years; the trees can be cut at 3-6 year intervals, whereupon the stumps resprout coppice-fashion. One hectare of ipilipil can regularly produce 35-50 cu.ms. of wood per year, while yields twice as high are not unknown.

The country that has accomplished most in the way of "energy plantations" is Philippines (U.S. Agency for International Development, 1978). Philippines believes that a 9000-hectare tree farm of ipilipil will produce enough wood to fuel a 75-megawatt power-plant— and the same could be accomplished by a 38,000-hectare plantation of gmelina, a 42,000-hectare plantation of Albizzia falcataria, or a 50,000-hectare plantation of eucalyptus. A wood-fired electricity-generating plant could not only compete economically with an oil-fired plant, but it could generate an estimated net saving of foreign exchange worth approximately $146 million in its first 10 years of operation (Semarna et al., 1977).

As an instance of a pilot scheme completed, a US AID-sponsored research project in Ghana shows that a 40,000-hectare plantation of fast-growing trees can produce energy equivalent to 500,000 metric tons of coal per year (together with food crops interplanted among the trees, around 60,000 tons of peanuts and 54,000 tons of corn). A capital-intensive plantation of the same size, but with sophisticated processing facilities, could produce 50,000 tons of methanol, 20,000 tons of pyrolytic oil, 150,000 tons of ammonia fertilizer, 17,000 tons of char, and 80,000 kilowatt hours of electricity per year (plus 60,000 tons of peanuts and 50,000 tons of corn) (Chiang et al., 1976).

Fast-growing annual crops

A third option lies with fast-growing annual crops. The biomass productivity of several species, already established in agriculture, is exceptionally high-notably sugarcane, one hectare of which can produce over 100 tons of biomass on good soil, each ton yielding 100-150 litres of alcohol.

The leading country in this field is probably Brazil (Hammond, 1977). Like many developing countries, Brazil faces a crisis of energy supplies, with energy consumption projected to increase at 10 percent per year for the foreseeable future. In order to relieve this problem, Brazil is utilising agricultural biomass to generate alcohol fuels. Any automobile will run off a mixture of 90 percent gasoline and 10 percent ethanol, while a modestly modified automobile will run off ethanol alone. Although alcohol has a calorific content 39 percent lower per litre than gasoline, alcohol has a higher density, and the power of a motor running off alcohol is 18 percent higher than a motor running off gasoline (which is why many racing cars run off a mixture that is predominantly alcohol). In 1977, Brazil produced 700 million litres of alcohol from sugarcane, and the 1978 figure may well have reached 1.5 billion litres. It is Brazil's aim that alcohol shall replace 20 percent of gasoline by 1980. Costs are estimated at around $1 per gallon; since this is rather more than the cost of producing alcohol from imported oil, the process is subsidised by the government.

Not only sugarcane serves the purpose. Brazil believes that a still more suitable species in the long run will be cassava—which would be especially suitable in Kenya, in view of its capacity to thrive in drier areas. Cassava's starch content is about 25 percent, almost twice as high as the sucrose content of sugarcane. This means that 1 ton of cassava yields considerably more ethanol than 1 ton of sugar. However, 1 hectare of sugarcane yields about 50 tons of disposable biomass, whereas 1 hectare of cassava produces only about 15 tons— and starch needs enzymatic action before it can be fermented. Despite these drawbacks, Brazil believes that cassava will surpass sugarcane in alcohol production within one decade. Indeed, Brazil believes that if it were to rely on sugarcane and cassava alone for its bio-energy sources, it would need to set aside only 2 percent of its total land area, or around 170,000 sq.kms., to replace all imported petroleum for its 120-million populace and its rapidly industrialising economy.

A third familiar agricultural plant is worth mentioning, even though Brazil does not use it. Sweet sorghum could prove useful as a grain crop for conversion to fuel, on the grounds that it contains sugar, by contrast with most other grain crops that contain starches that have to be converted into sugar before being fermented and turned into fuels. This characteristic enables sorghum to be readily converted into ethanol, and then used in the production of "gasohol". Furthermore, the sorghum stalks could be used to generate steam for electricity, or they could be converted into ethanol and ammonia (or even into pulp and paper products and plywood). According to research conducted by Dr. Steven Kresovich and Dr. William Lawton, agronomists with the Battelle Laboratories at Columbus, Ohio, U.S.A., some 40,000 sq.kms. of sorghum could produce 3 quads of energy (one quad equals one quadrillion BTU), equivalent to 1.5 million barrels of petroleum per day, for one year.

Hydrocarbon trees

Certain plant species can serve as sources of energy by virtue of their capacity to produce hydrocarbons like oil, instead of carbohydrates like sugar. These hydrocarbons come in various forms, one of which has long been used by man, rubber from Hevea brasiliensis of the Euphorbia family. Various other Euphorbias produce significant amounts of a milk-like sap, latex, that is actually an emulsion containing as much as 30-40 percent hydrocarbons in water (Calvin, 1977 and Buchanan and Otey, 1978; Nielsen et al., 1978). The hydrocarbons are similar to those produced by the rubber tree, but much lower in molecular weight, and with size distribution similar to those of hydrocarbons in petroleum. In point of fact, their hydrocarbons are superior to those of crude oil, since they are practically free of sulphur and contaminants found in fossil petroleum.

All in all, some 2000 plant species produce hydrocarbons. But the genus Euphorbia seems to be especially suitable for "growing gasoline", notably 12 Euphorbia species identified in Brazil, e.g. E. lathyrum and E. triculli, that contain about 10 percent by dry weight of hydrocarbon-like materials. Many members of this widely-distributed genus are to be found in Africa, and are adapted to growing in areas that are too dry for other conventional purposes such as agriculture. Thus they would be highly suitable for the nine-tenths of Kenya's territory that does not receive enough rainfall for present-day agriculture. Since areas with high insulation offer the best prospects for hydrocarbon plantations, one can visualise the potential that is possibly offered by Kenya's extensive aridlands.

Small-scale experiments indicate that one hectare of Euphorbia trees could produce between 25 and 125 barrels of oil per year, at annual production costs of about $20 per barrel, to be compared with current OPEC prices of around $14.50. Geneticists and agronomists are confident that production can be greatly increased through careful breeding; after all, natural rubber yields are no more than around

225 kgs. per hectare, but through genetic engineering they have been improved to 2250 kgs. per hectare in plantations, while certain hybrids yield as much as 5500 kgs., and yields following further research are forecasted to run as high as 9000 kgs.

Productivity trials for hydrocarbon trees are being conducted in Brazil, Mexico and California, while commercial plantations have already been established on Okinawa in the western Pacific by two large Japanese corporations, Nippon Oil and Sekisui Plastics.

Aquatic biomass systems

A final group of candidates for biomass-energy could include a number of water plants, notably certain algae, "freshwater weeds" such as water hyacinth, and marine species such as certain seaweeds and giant kelps (Avron and Bernatoz, 1975; Benemann, 1976; Hillman and Culley, 1978; Keenan, 1977; Poole and Williams, 1976; US National Academy of Sciences, 1976; Woodwell, 1977). For example, anaerobic digestion of algae biomass can produce methane at rates of 500 million BTU per hectare per year—and, as spinoff byproducts, the residue from the algal fermentation contains about 5 tons of nitrogen and several hundred kgs. of phosphates per hectare per year. As for seaweeds, trial research in California suggests it could prove a frontrunner source of energy: being carbonaceous, it can be processed by fermentation and anaerobic digestion into methane. In theory, a $2\frac{1}{2}$-sq.km. "marine farm" of one of the warmer seaboards of the tropics could generate enough energy (plus other products, notably fertilizer and plastics) to support at least 300 persons, and also grow sufficient food to feed 3000-5000 persons, at current world average consumption levels; while a 750-sq.km. area could produce as much natural gas as the United States consumes in one year (Alvin and Kozlowsky, 1978; Calvin, 1978; Wilcox, 1976).

Bio-energy and rural development

A notable feature of many bio-energy programmes is that they can include the explicit aim of promoting rural economic development. By utilising abundant raw materials in the countryside, by supplying energy for rural development, and by providing employment, these programmes can slow the run-away migration into urban areas that afflicts many developing countries. By contrast with energy produced through conventional large-scale generators, usually located in or near cities, bio-energy production can be centralised through a network of small-scale plants. Bio-energy can relieve the serious and growing problems of deforestation through fuelwood gathering. It is this aspect of bio-energy, viz, its capacity to meet an integrated package of rural needs, that offers benefits way beyond energy needs alone (Brown and Howe, 1978; Howe, 1977; Tanzania National Scientific Research Council, 1978; U.S. National Academy of Sciences, 1977).

REFERENCES

Alich, J.A. and R.E. Inman, 1974. Effective Utilization of Solar Energy to Produce Clean Fuel. Stanford Research Institute, Menlo Park, California, U.S.A.

Alvim, P. de T. and T.T. Koslosky (editors), 1978. Ecophysiology of Tropical Crops. Academic Press, New York, U.S.A.

Bassham, J.A., 1976. Sythesis of Organic Compounds for Carbon Dioxide in Land Plants. Report for U.S. Energy Research and Development Administration, Lawrence Berkeley Laboratory, University of California, Berkeley, California, U.S.A.

Benge, M.D. and H. Curran, 1976. Bayani: A Source of Fertilizer, Feed and Energy for the Philippines. Agricultural Development Seminar Series, US AID, Manila, Philippines.

Bente, P.F. (editor), 1978. Bio-Energy Director. The Bio-Energy Council, Washington, D.C., U.S.A.

Brown, N.L. (editor), 1978. Renewable Energy Resources and Rural applications in the Developing World. Westview Press, Boulder, Colorado, U.S.A.

Buchanan, R.A. and F.H. Otey, 1978. Multi-Use Oil- and Hydrocarbon-Producing Crops in Adaptive Systems for Food, Material and Energy Production. Northern Regional Research Centre, U.S. Department of Agriculture, Peoria, Illinois, U.S.A.

Calvin, M., 1976. Photosynthesis as a Resource for Energy and Materials. American Scientist 64: 270-278.

Calvin, M., 1977. The Sunny Side of the Future. Chemtech 7: 352-363.

Calvin, M., 1978. Green Factories. Chemical and Engineering News 56: 30-36.

Chiang, T.I., J.W. Tatom, J.W.F. de Graft-Johnson and J.W. Powell. Pyrolytic Conversion of Agricultural and Forestry Wastes in Ghana: A feasibility Study. Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, U.S.A.

Clifton, D.S. and J.W. Tatom, 1976. Energy-Food Plantations for the Third World. Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, U.S.A.

Earl, D., 1975. Forest Energy and Economic Development. Clarendon Press, Oxford, U.K.

Hammond, A.L., 1977. Alcohol: A Brazilian Answer to the Energy Crisis; and Energy: Brazil Seeks a Strategy Among Many Options. Science 195: 564-567.

Hayes, D., 1977. Rays of Hope. W.W. Norton, New York, U.S.A.

Hillis, W.E. and A.G. Brown (editors), 1978. Eucalyptus for Wood Production. Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia.

Hillman, W.S. and D.D. Culley, 1978. The Uses of Duckweed. American Scientist 66 (4): 442-451.

Howe, J.W., 1977. Energy for the Villages of Africa. Overseas Development, Council, Washington D.C., U.S.A.

Inman, R.E. et. al., 1977. Silvicultural Biomass Farms. Mitre Technical Report No. 7347. The Mitre Corporation, Virginia, U.S.A.

Johnson, N.E. 1976. Biological Opportunities and Risks Associated with Fast-Growing Plantations in the Tropics. U.S. National Research Council, Washington D.C., U.S.A.

Keenan, J.D. 1977. Bioconversion of Solar Energy to Methane. Energy 2: 365-373.

Mariani, E.O., W.A. Wood, P.C. Kouchoukos and M.B. Minton 1978. The Eucalyptus Energy Farm. Division of Solar Energy, U.S. Department of Energy, Washington D.C., U.S.A.

Myers, N. 1979a. Tropical Moist Forests as Source of Biomass-Derived Fuels. In: Proceedings of World Conference on Future Sources of Organic Raw Materials, July 10-13 1978, Toronto, Canada, Pergamon Press, New York and Oxford (forthcoming).

Myers, N. 1979b. Bio-Energy From Tropical Moist Forests. In: Proceedings of Second International Congress of Ecology, Session on Innovative Uses of Tropical Forest Ecosystems, Jerusalem, September 5-12 1978 (in press).

Nielsen, P.E., H. Nishimura, J.W. Otvos and M. Calvin 1978. Plant Crops as a Source of Fuel and Hydrocarbon-Like Materials. Science: 942-944.

Pollard, W.G. 1976. The Long-Range Prospects for Solar-Derived Fuels. American Scientist 64: 509-513.

Poole, A.D. and R.H. Williams 1976. Flower Power: Preliminary Survey of the Potential and Problems of Utilising Solar Energy via Photosynthesis. Bulletin of Atomic Scientists 32(5): 47-58.

Poole, A. 1977: Energy from Biomass: A Conceptual Overview. Institute for Energy Analysis/Oak Ridge Associated Universities, Washington D.C., U.S.A.

Rose, D.W. 1977. Cost of Producing Energy from Wood in Intensive Cultures. Journal of Environmental Management 5: 23-35.

Semarna, J.A., P.V. Bawagan, F.R. Siriban, and V.B. Mendoza, 1977. A Feasibility Study of the Utilisation of Man-Made Forests for Generating Electricity. Forest Products Research and Industries Development Commission, National Science Development Board, College, Laguna, Philippines.

Tanzania National Scientific Research Council, 1978. Workshop on Solar Energy for the Villages of Tanzania. Tanzania National Scientific Research Council, Dar es Salaam, Tanzania.

Tatom, J.W., A.R. Colcord, J.R. Knight, and L.W. Elston, 1976. Clean Fuels From Agricultural and Forestry Wastes. Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, U.S.A.

U.S. Agency for International Development, 1978. Philippines: Non-Conventional Energy Development. Project Paper AID-DLC/P-2288, Department of State, Washington D.C., U.S.A.

U.S. National Academy of Sciences, 1976. Making Aquatic Weeds Useful. U.S. National Academy of Sciences, Washington D.C., U.S.A.

U.S. National Academy of Sciences, 1977. Energy for Rural Development: Renewable Resources and Alternative Technologies for Developing Countries. U.S. National Academy of Sciences, Washington D.C., U.S.A.

U.S. National Research Council, 1977. Leucaena: Promising Forage and Tree Crop for the Tropics. U.S. National Research Council, Washington D.C., U.S.A.

Whittaker, R.H. and G. Likens, 1975. In: H. Leith and R.H. Whittaker, (editors) Primary Productivity of the Biosphere. Springer Verlag, New York, U.S.A.

Williams, R.H. (editor), 1975. The Energy Conservation Papers. Ballinger, Cambridge, Massachusetts, U.S.A.

Wilcox, H.A. 1976. The Ocean Food and Energy Farm Project. Naval Undersea Center, San Diego, California, U.S.A.

Woodwell, G.M. 1977. Recycling Sewage Through Plant Communities. American Scientist 65: 556-562.

PROSPECTS OF GEOTHERMAL ENERGY IN KENYA

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ABSTRACT

In a developing country like Kenya, whose energy demands are constantly increasing and which imports most of its raw energy mainly in the form of oil, it is essential that any indigenous energy resources should be explored and exploited. One of the most promising energy resources capable of development is geothermal energy. Within the Kenyan Rift Valley there are several areas with active surface geothermal manifestations. These areas extend from the Lake Logipi area in the north to the Lake Magadi area in the south. Geological and geophysical studies have presented evidence that the Kenyan Rift Valley is underlain by a hot intrusive body up to approximately 20 km wide which extends to shallow depths below the surface. This body provides the heat for the observable surface geothermal phenomena. A systematic study of three geothermal provinces within the Rift Valley was undertaken by the UNDP/EAPL Co. from 1970. At one of these provinces (Olkaria) studies have shown that there are sufficient reserves to supply at least 4200 MW years of power. A pilot geothermal power station is being constructed at this site to harness subterranean steam from a few boreholes for power generation. The advantages of utilizing geothermal energy in Kenya are discussed. Other areas within the Kenya Rift Valley with potential for providing geothermal energy are presented. It is suggested that a systematic exploration study of these areas ought to be carried out.

INTRODUCTION

The purpose of developing geothermal energy in Kenya is to provide a competitive source of power from an indigenous energy resource with the view of reducing the country's dependence upon imported raw energy mainly in the form of oil. Kenya is energy deficient but being a developing country its rising standards of living depend upon greater use of energy for industrial, commercial and domestic purposes. This makes it vulnerable to the ever rising prices of oil and also contributes a drain of valuable foreign exchange.

Kenya has vast potential of geothermal resources. A large part of the Kenyan Rift Valley is characterized by intense geothermal activity. This is in the form of geysers, steam fumaroles, warm and hot springs. The areas of active surface manifestations of geothermal activity extend from Lake Logipi, just south of Lake Turkana, in the north to Lake Magadi in the south. The exploitable geothermal potential would be, by rough estimates more than sufficient to supply the country with all its power needs.

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* The views expressed in this paper are those of the authors and should not necessarily be attributed to the University of Nairobi or anybody else.

Increased attention has been given to the exploration and subsequent exploitation of geothermal resources since the United Nations cooperation with Kenya in the geothermal exploration of 1970–1975. Detailed geological, geophysical, geochemical and drill hole studies were made of the geothermal potential of areas near Lake Naivasha and Lake Bogoria while a considerable amount of preliminary data was obtained from other geothermal prospects within the Rift Valley. Based on the results of this work the first geothermal power plant capable of producing 15 MW of power is being constructed at Olkaria, an area south of Lake Naivasha. The output of this geothermal power plant is to be progressively increased following the completion of the first construction phase until the maximum output capacity of approximately 170 MW is achieved. This contribution of geothermal energy towards the total energy needs of Kenya promises to be significant.

SOURCES OF ENERGY IN KENYA

Present day Kenya obtains most of its energy needs from the use of oil, hydro-electricity and coal. The total energy consumed in Kenya in the Modern economic sector comprises 85% from oil, 12% from hydro-electricity and 3% from coal (Mathenge, 1978). The energy consumption has continued to rise at a rate of approximately 8% per year over the last 10 years. All the oil, coal and approximately 25% of the hydro-electricity consumed in Kenya is imported and has to be paid for in foreign exchange. Since the price of Crude oil went up in 1973/74, Kenya, among many other countries, has experienced serious balance of payment problems (Maitha, 1978).

Other adverse effects since the 1973/74 oil crisis on Kenya included a deceleration of the economic growth momentum, inflation and a drop in the standards of living of Kenyans. Moreover Kenya's Crude oil supplies are dependent on the political climate in the Middle East. From the recent political developments in that region it is feared that future Crude oil supplies may be unpredictable and when available their price will continue to rise and the result will be a continued balance of payments crisis and increased inflation in oil-importing countries like Kenya. To reduce these effects alternative energy sources are being sought and developed within the country. The most promising ones are hydro-electric and geothermal power and wood. The projected electric energy consumption for 1979 in Kenya is 1652 GWHr (1GWHr = 10^6KWHr) (Gecau, 1978), 15% of which is imported from Uganda Electricity Board, 25% from thermally-powered stations, and 62% from locally produced hydroelectricity. By 1982 Kenya may consume approximately 2100 GWHr of electricity of which about 150 GWHr will be from geothermal power stations, while by 1990 Geothermal power stations may be supplying approximately 360 GWHr (10%) of the 3680 GWHr of electricity that may be needed then.

Geothermal Resources and the Kenya Rift Valley

Geothermal resources are derived from the natural heat of the earth's crust. This natural energy is economically significant only when it is concentrated into restricted volumes at shallow depths (3km). Fig. 1 shows a typical geothermal system. The location of a geothermal system is determined by the intrusion of a deep igneous mass (at perhaps 5 km depth) which is the heat source driving the overlying convection system. An anomalous temperature regime of the upper few kilometres is imposed on whatever rock units there are. In exploring for geothermal prospects we search for either a manifestation of magmatic intrusion or

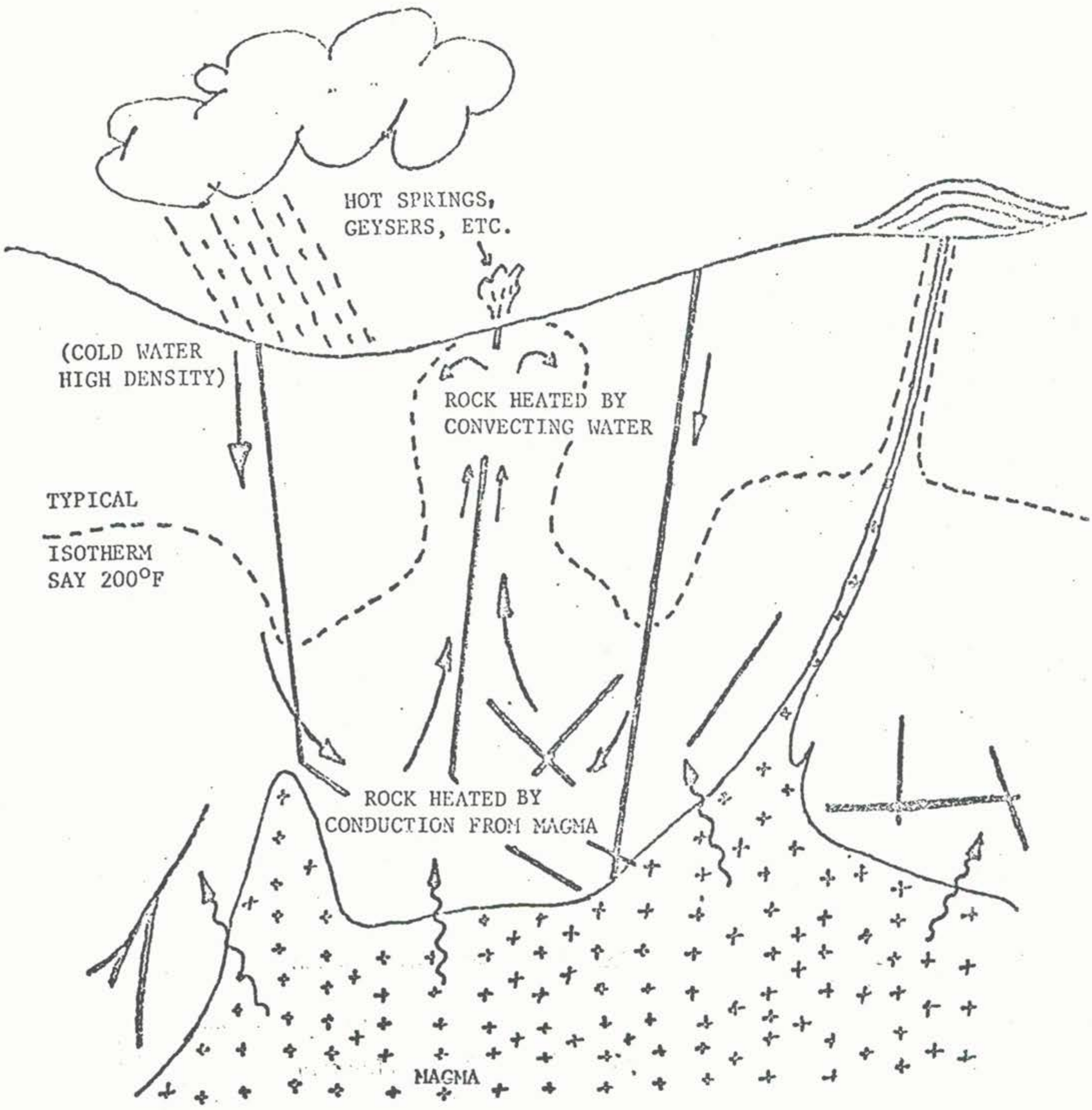

FIG. 1 GENERALIZED MODEL OF HYDROTHERMAL SYSTEM

(MODIFIED FROM WHITE, 1967)

its hydrological - geothermal effects and because of this, geothermal energy research and development focusses mainly on areas of recent volcanism.

The Kenya rift valley is part of the East African rift system which is linked to the world wide system of mid-oceanic ridges via the Afar triple function and the Gulf of Aden rift. The world wide system of mid-oceanic ridges represent divergent plate boundaries characterized by high heat flow, young volcanism and geothermal activity. Various geophysical studies have been made in Kenya to determine the structure of the crust and upper mantle in the rift valley region. The results of these studies are consistent with a model comprising the swelling of the asthenosphere into the lower part of the lithosphere under the Kenya 'dome' and dyke-like intrusions of hot material, perhaps rooted in this asthenolith, appear to reach within a few kilometres of the surface under the floor of the rift valley and are responsible for recent volcanism and observed geothermal activity (Skinner, 1977). The dyke-like intrusion under the rift floor is believed to extend over a width of about 20 km in the upper part of crust (Searle, 1970).

Besides the existence of the necessary heat sources supplying the required thermal energy the Kenyan rift valley is topographically and geologically well - structured to have the components necessary for efficient geothermal systems. The topography allows for the existence of surficial and underground internal hydrological recharge systems which provide an adequate water supply, while the numerous fractures and porous volcanic rocks in this region allow easy fluid mobility; both of which are necessary for efficient geothermal systems.

The most promising areas for geothermal resource research and development in the Kenya rift valley are shown in Fig. 2. These areas have been identified by direct observations of surficial geothermal effects such as geysers, hot and warm springs, fumaroles, steaming and hydrothermally altered grounds. Of these areas Olkaria, Eburru and Lake Bogoria were given priority for research, drilling and development by the UNDP/EAPL geothermal exploration group.

Olkaria geothermal area lies immediately south of Lake Naivasha. The hydrothermal activity at Olkaria consists of fumaroles, steaming and hydrothermally altered grounds. There are several linear zone of fumarolic activity all of which are located within an ancient buried ring (Caldera) structure and to the east of the main Olkaria fault. The greatest concentration of fumaroles is within 1 km of the young major (Ololbutot) N-S fracture zone of young volcanoes and lava vents. Geological, geophysical and chemical studies have been used to delineate the geothermal reservoir which has been estimated to extend over an area of 50 km^2. The current drilling programme by the Kenya Power Company aims at harnessing subterranean steam from electric power generation from various bore-holes confined over an area of 12 km^2 within the geothermal field.

Eburru geothermal area is located to the north-west of Lake Naivasha. Like at Olkaria, the distribution of the superficial hydrothermal activity is related to the N-S fracture patterns which are in turn related to the major dislocations that provided loci for the young volcanism. At Eburru the hydrothermal activity which consists of fumaroles and high grade hydrothermally altered grounds, occurs over an area of approximately 40 km^2 along and to the west of the main Eburru fracture zone in a 4-km wide N-S trending graben within which also lie various summit crates aligned on E-W traverse lineations (Noble and Ojiambo, 1977).

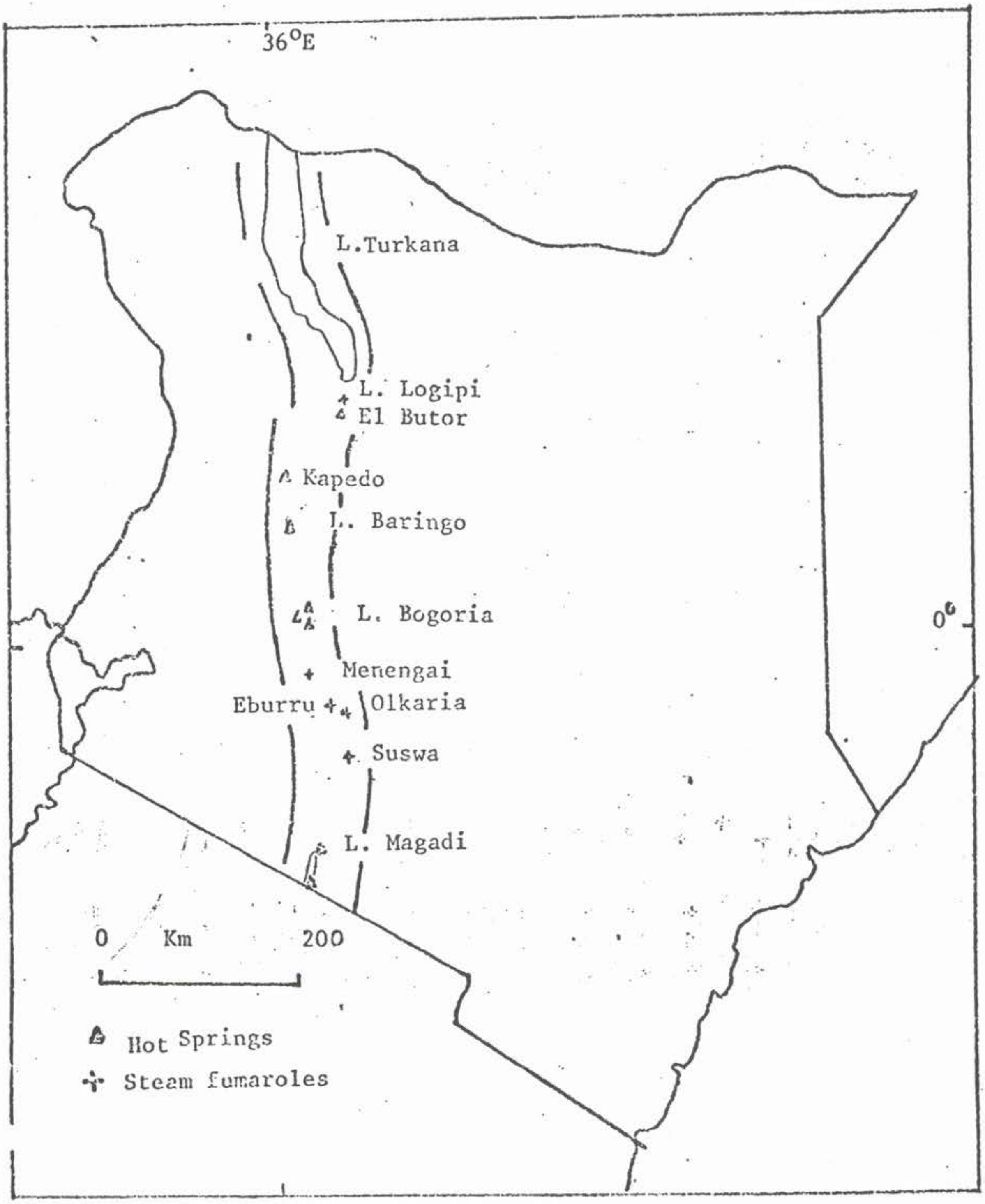

Fig. 2 Location of hot springs and fumaroles in Rift Valley of Kenya.

At Lake Bogoria surface geothermal activity consists of a geyser, hot and warm springs and thermally altered grounds located to the southwest, south and southeast of the lake. There is no evidence for recent volcanism in this area, however, a close relationship has been found to exist between the numerous north-southerly trending faults in this area and the thermal springs (Naylor, 1972). On the basis of resistivity mapping (Bhogal, 1978) the southwest part of Lake Bogoria promises to have the greatest thermal potential. A surface area of approximately 15 km^2 is characterized by relatively lower resistivity values.

Little geothermal exploration work has been carried out at the other geothermal prospects in Kenya beyond identifying the surface geothermal activity present. A systematic exploration program is needed to evaluate the geothermal potential of each of these areas.

Exploration for geothermal resources

The commodity being sought in exploration for geothermal resources is heat. If the geothermal resources is restricted to the generation of electricity by convectional steam-fed turbines then the temperature of the reservoir must be greater than 180 C and the reservoir must have adequate permeability and water to allow the heat to be extracted. Fluids at temperatures of 40 C to 180 C can be used for agricultural heating, product processing, electricity generation via a heat exchanger and cold vapour (freon or Iso-butane) cycle, and mineral recovery; all of which are important in Kenya.

The initial exploration programme consists of the obvious methods of direct observations of geothermal effects such as geysers and hot springs and a review of the available geological literature. This is followed by indirect measurements and observations which include thermal surveys used to map the hot areas; geological studies used to identify faults, hydrothermal altered rocks and structures related to geothermal activity; and geophysical studies using gravity, seismic and electrical methods used to delineate the geothermal reservoirs. The results of the above studies are then used to define a drilling programme and the subsequent development of the geothermal resources. It is our opinion that the integrated exploration programme just outlined will have to be carried out at all the potential geothermal areas in Kenya in order to access their potential and recommend a development programme.

Advantages of Utilizing geothermal energy in Kenya

The timing and extent of geothermal power exploration hinges on the prevailing economic situation. The development of geothermal energy in Kenya has become particularly attractive due to the uncertainly of future oil coupled with the regular increases in the price of the available oil supplies and their effects on the nation's balance of payments. Since geothermal power plants operate on an indigeneous energy resource foreign exchange costs are minimal. The absence of any fuel cost for a geothermal power plant means that pratically all the operating costs are fixed in nature.

Compared to its closest rival as an indigeneous energy source, hydroelectric power, the capital as well as operating costs for geothermal power plants are less by about 45% (Ojiambo, pers. comm.). Whereas the cost of geothermal exploration may be high, geothermal exploitation lends itself particularly to the installation of power generating units in comparatively small sizes. Thus the development of geothermal resources in any area would be based on a continuing program resulting in the regular installation of small power plants whose size may be increased in step with the increase in consumer demand for electricity. Technically geothermal power installations are uncomplicated and extremely simple to operate. They do not contain the complicated high pressure plants found in thermal power stations, nor do they require fuel storage facilities.

Geothermal energy can also be used on a multipurpose basis. In areas such as Lake Magadi and Bogoria with deficient fresh water supplies geothermal power plants can be used to provide drinking water through the medium of multistage flash distilling plants. For a long time drinking water has been obtained by condensing steam from the fumaroles at Eburru in sloping galvanized pipes. Steam has also been used for drying pyrethrum flowers at Eburru. Such applications can be refined and expanded to cover other areas.

The main handicap of geothermal power utilization involves the management of corrosive and poisonous residual fluid wastes. One proposed solution to this problem involves the re-injection of the effluent back into the underground rock formation. Since the geothermal resource areas are far from centres of large populations the problems of air pollution by the gaseous bi-products and noise pollution may not be significant. However, appropriate solutions could be found.

CONCLUSION

The contribution of geothermal energy to Kenya's energy needs promises to be significant. Several areas located within the Kenya rift valley display surface geothermal manifestations in the form of geysers, hot and warm springs, fumaroles and hydrothermally altered grounds. A comprehensive geothermal exploration program is proposed in order to evaluate the geothermal potential of each of these areas. The results of exploration studies at three sites: Olkaria, Eburru and Lake Bogoria, have been promising. On the basis of these results a geothermal power plant is under construction at Olkaria and this will soon provide Kenya with its first geothermal power supply.

REFERENCES

Bhogal, P.S. : The electrical resistivity method of geophysical prospecting and its application to geothermal exploration in the rift valley of Kenya. Ph.D. thesis University of Nairobi, (1978).

Gecau, J.K. : Introduction - Modern economy. Paper submitted to The Energy Symposium, Nairobi, November, (1978).

Maitha, J.K. : Energy: Balance of payments implications. Paper presented at the National Energy Symposium: Coping with the energy crunch in a growing Kenya, Nairobi - November, (1978).

Mathenge, J.S. : Financing energy development. Paper presented at the National Energy Symposium: coping with the energy crunch in a growing Kenya. Nairobi - November, (1978).

Naylor, W.I. : Geology of the Lake Hannington prospect. Unpubl. report to the UNDP/EAPL geothermal exploration Project, (1972).

Noble, J.W. and Ojiambo, S.B. : Geothermal exploration in Kenya. In 2nd U.N. Symposium on the development and use of geothermal resources, Vol. 1. 198-204, (1975).

Searle, R.C. : Evidence from gravity anomalies for thinning of the lithosphere beneath the Rift Valley in Kenya. Geophy J.R. astr. soc. 21 13 - 31, (1970).

Skinner, N.J. : Recent geophysical studies of the Kenya rift valley. Contemp. Physics 18: 455 - 470, (1977).

REFLECTIONS ON ENERGY WITH SOME REFERENCE TO TANZANIA

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INTRODUCTION

Energy utilisation and economic development are closely linked. According to Cipolla (1), the more successfully man can use his own energy to control and put to use other forms of energy, the more he acquires control over his environment and achieves goals other than those strictly related to animal existence. Thus it is clear that the more man can substitute muscle energy by another form of energy, the more tasks in agriculture, industry, domestic chores etc. can be performed more efficiently. However, the story of man's utilisation of energy has shown an ever increasing demand of energy up to the present decade when we have witnessed an escalating energy utilisation, referred to as the energy crisis. The concept of energy crisis has however, to be viewed carefully within the context of whether one is in the developed or developing world. There appears to be four main reasons that have led to the present crisis. Firstly, for physical reasons, geological or otherwise, the energy resources that have been exploited most are being depleted at a very fast rate. This includes fossil fuels, consumed mostly by the developed world, and firewood, which is consumed in the developing countries. Secondly, for environmental reasons, man has unconsiously disturbed the balance in nature. This is exemplified by pollution, desertification and other such effects. Thirdly, economically, the price of fossil fuels has been increasing exponentially, and consequently the third world countries have to spend a lot of their hard earned foreign currency. Fourthly, fossil fuels have been associated with formation of blocks of countries and hence making this energy commodity serve as a political weapon. In this paper we propose to survey some fundamentals of the energy concept.

SOME FUNDAMENTALS OF ENERGY

Forms of energy

Energy exists in several forms as is summarised in Table 1.

Table 1: Forms of Energy
MECHANICAL
HEAT
LIGHT
ELECTRICAL
MAGNETIC
SOUND
CHEMICAL
NUCLEAR

Three of the fundamental facts about energy are; first energy is conserved. Secondly, energy can be converted (or transformed) from one form to another, and thirdly energy can be measured and thus quantified. In any utilisation of energy, the principle of conservation of energy must be taken into account by designing the most efficient devices which minimise energy losses, and of course, the efficiency can only be within physical limits as set for example by the second law of thermodynamics. The property that energy can be converted from one form to another can also be exploited, for example by storing the energy in a form whereby energy losses are minimal. For example in wind systems, energy may be stored in a battery in form of chemical energy, which can be utilized when wind speed has reduced. The fact that energy can be measured leads us to the consideration of quantifying energy, and the unit being the JOULE. Other units related to the Joule are given in Equation (1)

$$\left.\begin{aligned} 1 \text{ Joule} &= 0.239 \text{ calories} \\ &= 9.48 \times 10^{4} \text{ B.T.U.} \\ &= 10^{7} \text{ Ergs} \\ &= 6.24 \times 10^{28} \text{ eV} \end{aligned}\right\} \quad (1)$$

Energy utilised per unit time constitutes what is referred to as Power, and the unit of power is the WATT.

$$1 \text{ Watt} = 1 \text{ J/s} = 1{,}34 \times 10^{-3} \text{h.p.} \quad (2)$$

Another unit which is frequently encountered in energy considerations is the energy per unit mass or the energy per unit volume. This defines the calorific value and the units are J/kg, J/m^3, cal/kg and Cal/m^3. For example charcoal has the calorific value ranging from 27.4×10^6 J/kg. to 30.0×10^6 J/kg.

Sources of energy

Man has exploited several sources of energy, and we summarize the list of energy sources in Table 2. The availability of these energy sources varies from one country to another depending on several geological and geographical factors.

Table 2: Energy Sources

FOSSIL	COAL GAS OIL
FORESTS	FIREWOOD CHARCOAL
HYDROPOWER	HYDROELECTRIC SYSTEMS PRIME-MOVER SYSTEMS HYDRAULIC RAM
WIND	HORIZONTAL AXIS SYSTEMS VERTICAL AXIS SYSTEMS

Table 2: Energy Sources contd.

SOLAR ENERGY	THERMODYNAMIC SYSTEMS PHOTOVOLTAIC SYSTEMS
BIOGAS	ANAEROBIC DIGESTION
GEOTHERMAL	GEOTHERMAL FLUID PRODUCTION
NUCLEAR	FISSION FUSION
OCEAN POWER	WAVE ENERGY OCEAN THERMAL GRADIENT

Each country, therefore has to analyse its potential energy resources and have a clearly defined energy policy that will plan to exploit the resources in an efficient manner. The situation in Tanzania is further discussed in section 3.

Tasks requiring Energy

The physicists definition of energy as the capability to do work will readily be appreciated. The problem of having an energy source is one, and the ability to harness the energy is another, and the ability to distribute and utilise the energy produced is yet another. One can summarise the various tasks requiring application of energy as shown in Table 3. The classification is purely for guidance and there is a lot of overlap.

Table 3: Tasks requiring application of energy

INDUSTRIAL	PROCESSING DRYING SPINNING CUTTING SEWING
AGRICULTURAL	CLEARING PLOWING PLANTING WATER PUMPING FERTILIZING WEEDING HARVESTING THRESHING DRYING GRINDING

Table 3: Tasks requiring application of energy

SOCIAL AND OTHERS	COOKING LIGHTING HEATING SPACE COOLING REFRIGERATION PASTEURIZATION DISTILLATION DESALINATION DEHUMIDIFICATION BUILDING
TRANSPORT	INDUSTRIAL PRODUCTS AGRICULTURAL PRODUCTS PEOPLE
TELECOMMUNICATIONS ...	COMMUNICATION

ENERGY RESOURCES IN TANZANIA

The energy sources have been summarised in Table 2, and Tanzania only processes some of these. For example we do not as yet have any nuclear power stations, though of course with possibilities of uranium deposits existing, such a possibility may not be totally out of place in future. In this section, therefore, we shall mainly concentrate on the energy resources that are of impact at present.

Fossil fuels

Coal resources

Tanzania has nine known coal field situated in the southern and south-western parts. The major coal fields and their reserves are show in Table 4. (2)

Table 4: Major coal fields in Tanzania

Coal fields	Proved Million tons	Reserves (Million tons)
Ketewaka Mchuchuma	186.6	495
Ngaka	97.7	152
Songwe Kiwira	20	495

At present STAMICO (State Mining Corporation) is operating a small colliery at Ilima in the Songwe Kiwira coal fields and the production in 1977 was 3,000 tons, which was about three times the country's demand. Most of this was used for brick-making purposes. Expansion is expected to enable production of 20,000 tons in 1980, and this will be coupled by increase coal demand in the pulp and paper factory at Mufindi, the Cement plant at Mbeya, and possibly for tobacco curing in Tabora region if present studies on this possibility prove positive. Since there are iron deposits in the adjacent areas of the coal fields, there is great potential for an iron and steel industry. The country's present development plan has laid emphasis on the industrial sector.

GAS

Gas has been found in Songo Songo area, 400 km south of Dar es Salaam. Estimated reserves amounting to 3.0×10^{13} cubic metres have been discovered. TPDC (Tanzania Petroleum Development Corporation) is the sole corporation entrusted with prospecting and necessary plans for exploitation of the gas deposit. The gas project will utilise about T.Shs 76,300,000 in the period 1975 - 1980.

OIL

At the present moment Tanzania does not have any oil wells, and consequently all her oil is imported. Petroleum, one of the oil products plays a unique role in any nation, mainly because of its versatility as an energy source, being able to produce several forms of energy (see table 1) due to its chemical properties. A large proportion of oil utilisation was:-

Transport	55.9%
Industry	17.3%
Household	11.8%
Electricity generals	5.7%
Construction	9.3%

There is no doubt that transport will still continue to take a large proportion of the oil in view of the extensive area of Tanzania and its dependence on agriculture. Like all other countries in the world, consumption of oil has increased. From 337,000 Miones in 1975 to 65,000 Miones in 1974. Tanzania has a sunday afternoon driving ban on non-commercial vehicles as a measure of energy conservation.

Forests

In Tanzania as in other African countries the main source of household energy of rural communities is derived from forest and plant material. The demand for firewood and charcoal by a rapidly increasing population can no longer be satisfied without the destruction of the general environment. In some parts of Tanzania, for instance the semi-arid regions of Dodoma, Singida, Tabora and Shinyanga the deterioration of the habitat is being further aggravated by excessive grazing, crop cultivation and compaction and damage to the soil. In other instances tobacco growing has resulted in the clearing of large areas of woodland to provide not only room for growing the crop but also the firewood that is used to "cure" the leaf in specially constructed tobacco barns.

Nowhere in Tanzania is the problem of desertification better exemplified than in Dodoma where the cattle population (3 million) exceeds the human population. Serious soil erosion has occurred widely in this area with the result that productivity from the land has tended to decline and firewood and charcoal have become scarce.

To reverse this process Government has embarked on a programme of better management of the land involving destocking, control of erosion by afforestation and improved cultivation methods. The restoration of vegetation by replanting on the better sites with species (Eucalyptus and Ãcacia species) best adapted to existing conditions is being undertaken on a district wide basis in Dodoma and is being emulated in neighbouring districts.

Firewood

Of the Tanzania 17 million people, over 90% live in the rural areas and their two main sources of energy are muscular energy and firewood. The energy crisis that is experienced by the rural community is the depletion of forests, and hence longer distances to where firewood can be gathered. Demand for firewood is estimated to be 2 cubic metres per person per year. With Tanzania's estimated 8,000 villages, with an average of 1,500 persons per village, one obtains a staggering figure of a demand of 3,000 cubic metres of firewood per year per village. The hazards of unchecked firewood gathering are environmentally unacceptable, leading to a disturbance of natural ecosystems. In Appendix A we show extrapolated fuelwood/ poles demand for the next five years as provided by the forest division of the Ministry of Natural Resources and tourism.

Charcoal

Most of the urban population in Tanzania use charcoal stoves for their cooking, and charcoal has become increasingly expensive in recent years, and now a sack of charcoal sells at 40/=. Charcoal production is by four main techniques shown in Table 5, and the earth kiln which is labour intensive is the most common and dependent on local skills entirely (3).

Table 5: Charcoal production techniques

Technique	Capital Cost (T.Shs)	Depreciation Period	Man Days per ton
Earth kiln	-	Immediate	26
Mark V	5,000.00	3 years	4
Missiuri kiln	60,000.00	7 years	1
Lambiotle Retort	7 million	30 years	0.5

Hydropower

Tanzania's hydroelectric potential is estimated to be 1400 MW (4), and so far only 262.5 MW exploited of which 14.5 MW generated by private organizations and rest generated by TANESCO (Tanzania Electric Supply Company).

TANESCO is the sole corporation entrusted with the generation, transmission and distribution of electricity in the mainland of Tanzania, while in Zanzibar the counterpart is the State fuel and Power Corporation. The main hydroelectric power stations in Tanzania are shown in Table 6 (5).

Table 6: Major Hydroelectric Stations

Location:	Capacity (MW)
Kidatu*	100
Hale	21
Pangani falls	17
Nyumba ya Mungu Same	8
Kikuletwa (near Moshi)	2

* Extension of Kidatu to a capacity of 200 MW has already been started. Other projects are the Kagera basin project in collaboration with Rwanda and Burundi the Stigler's gorge project in the Rufiji basin, and Zanzibar will be fed by the Coastal Grid System of the mainland.

Wind:

Windmills have been used to deliver mechanical power for grinding grain and pumping water for over 1000 years, and for nearly a century for generation of electrical power. Use of Windmills have largely declined in the sixties and seventies as a result of fossil fuel systems which were relatively cheaper by them. However, of recent there has been a remarkable renewed interest in wind energy systems. Of course as is commonly observed, wind speed is time dependent and hence such fluctuations make the power available from wind to be varying with time. For a wind of speed V and density, passing through a disk of cross-sectional area A, the kinetic energy, E available in time t from the wind is given by:-

$$E = \frac{1}{2} mV^2 = \frac{1}{2} \rho A t v^3 \qquad (3)$$

The power (P) which is energy available per unit time, is given by:-

$$P = \frac{E}{t} = \rho A V^3 \qquad (4)$$

Not all of the power given in equation (4) is available for extraction by a wind driven machine. If all the wind energy were extracted by the rotor, airflow would cease, which is unphysical. Physically, on the transmission side of the rotor, the wind velocity is finite, say u_1, which is less than the incident velocity V infront of the rotor in the incidence side. If the wind velocity through the rotor is u, the power extracted (Pext) by the turbine is given by:-

$$Pext = \frac{1}{2} \rho A u \left(V^2 - u_1^2\right) \qquad (5)$$

and this equals the kinetic energy lost by the wind in passing through the turbine. The ratio (Cp) of the extracted power to available power is

$$Cp = \frac{Pext}{+p} \qquad (6)$$

By using momentum conservation and Bernoulli's equation, the maximum theoretical value of Cp is found to be (6) given by:-

$$\frac{(Pext)}{P} = \frac{16}{17} = 59.3\% \qquad (7)$$

The efficiency, n, of a wind energy machine is defined with respect to the maximum power extractable is given by:-

$$\eta = \frac{(Pext/P)}{(Pext/P)\ max} = \frac{Cp}{0.593} \qquad (8)$$

There are two important observations we have noted in the proceeding discussion on wind mills. First, the cubic dependence of the power available implies that the location of turbines is a very important consideration. For example for a wind of density $S = 1.22\ Kg/m^3$ at 10 m.p.h. the power per unit area (wind intensity) is 55 W/m^2, while at 20 m.p.h. the wind intensity is 440 W/m^2.

This shows that at twice the wind velocity one has an intensity eight times larger. Secondly, since the maximum extractable power is only 59.3% of the available power, most turbines used for producing electricity have a low efficiency, about 15% to 75%. There are a few windmills in Tanzania, mainly installed by MAJI, TANESCO, UNIVERSITY and some MISSIONARIES. In Shinyanga, for example, there is a 3m diameter windmill rotating on a horizontal axis and placed on a bore hole 20m. deep. This windmill is fitted with a 3 in. pump cylinder and has been observed to deliver about 4 cubic metres everyday at average wind speeds of 12 km per hour. Maintenance is minimal and can be done by local skills available at village level.

Solar Energy

Solar energy available in sunlight has been a subject of considerable research in recent years. In Dar es Salaam, for example, there are approximately 20,000 hours of sunshine per year. For order of magnitude calculations, we may obtain the solar intensity on the earth's surface by considering the power radiated by the sun as 3.8×10^{26} watts. This power falls onto the earth which is about $1.5 \times 10m^{11}$ away from the sun. The power per unit surface area (called the Poynting Vector in electromagnetic theory) is given by S,

$$S = \frac{\text{power}}{4\pi\,(\text{radias})2} = \frac{3.8 \times 10^{26}}{4\pi\,(1.5 \times 10^{11})\,2} = 1340 \text{ Watts/m}^2 \quad (9)$$

The magnitude of the Poynting Vector given in Equation (9) implies approximately 6.9×10^{17} watts fall on the earth's surface on a cloudless day. Of course this figure varies as one moves from the equator to the poles. Further, about 30 - 35% is reflected back to space (total albedo), 19% is absorbed by the earth's atmosphere and about 2% is captured by green vegetation and the rest is absorbed by the land surface. Precise evaluation of solar energy intensity depends on the spectrum, incident angle, cloudiness, position etc. All these parameters require accurate data. There are several institutions in Tanzania showing interest in solar energy devices. There is some documentation of the potential of solar energy utilisation in Tanzania in the proceedings of the workshop on solar energy held during August 11-19, 1977 under the joint sponsorship of the Tanzania National Scientific Research Council and the U.S. National Academy of Science (7).

The department of physics of the University of Dar es Salaam has identified solar energy research as a priority area. Some work on solar energy by selectively absorbing surface has been done in the department by Lushiku (9) and Kivaisi (10). There have been also a study of solar devices, basically thermodynamic systems, such as solar stills, solar water heater (11) and solar oven (12). Depending on availability of funds plans are underway to fabricate systems based on photovoltaic conversion of the photon energy in the sunlight to electricity. This needs expensive equipment such as a High vacum system costing some T.Shs 200,000/= (Approx. 24,000 U.S. Dollars) and our efforts to get such an amount have not been successful. It is clear that for meaningful and serious research most institutions need enough funds to set a base.

Biogas

Waste products (the present terminology which may change in the future) from human, animal and agricultural products could prove to be very useful source of energy by utilising anaerobic digestion whereby approximately 55% methane 45% carbon dioxide can be realised and a residue rich in nitrogen and humus can serve as a valuable fertilizer. The methane gas produced can be used for cooking, heating, lighting and for motive power. Several biogas plants are operating in Tanzania as listed in Appendix B. The Small Industries Development Organisation (SIDO) has been responsible for the running of most of these biogas plants. Typical gas production plants show that a cow gives about 15 kg of dung and a calf about 5 kg of dung per day. Gas production per kilogram of wet dung is about 1.3 cu.ft.

Geothermal

Four areas in Tanzania have been identified as having geothermal reservoirs in Ngorongoro, Mbeya, Dodoma and in the Rufiji basin (Kisasi). These areas were identified as a result of geothermal prospecting by Swedish and Iceland consultancy groups, SWECO and VIRKIR respectively. Recently (March, 1979) there was a two day Geothermal Symposium in Dar es Salaam with interdisciplinary experts from (GERD) Geothermal Energy Research and Development Company) of Japan. Geothermal fluid production involves well-drilling technology which has some resemblance to oil drilling, but for geological reasons oil and geothermal reservoirs do not normally occur in the same areas. A steam producing well could be up to 1,500 m. deep and a test well up to 1,000 m. deep. Apart from power production, the hot water component of the geothermal fluid can be used for several task. At present Tanzania is not utilising any Geothermal energy.

ENERGY R AND D AND CONCLUDING REMARKS

Tanzania like most developing countries must learn to be energy conscious and hence there is a necessity for an Energy policy. Among other things such a policy would necessarily have short and long term programmes in energy utilisation for urban and rural areas, a programme on harnessing of the energy resources and so on.

It has already been pointed out earlier that the energy crisis must be viewed in its proper perspective in developing countries. Most of the people in the rural areas are touched by the firewood crisis rather than fossil fuels crisis. There is need therefore to concentrate R and D efforts on finding energy technologies ultimately applicable in the rural areas. Amongst other questions on renewable energy technologies one needs to ask:

(i) Does the technology meet a local need?

(ii) Is it compatible with local resources and skills?

(iii) Is it ecologically and environmentally sound?

(iv) Is it socially and economically acceptable?

(v) Is it dependent on local R and D?

Since the energy problem has long been neglected, there is a lot of scope for study right from first principles. Energy has always been taken for granted, and there is need to educate the masses on intelligent consumption of energy. The authors are of the opinion that there are several areas which need a systematic study, and amongst others we think the following need immediate attention:-

(i) Regional variation in energy supply and demand. This should include the major energy deficit in each region and the potential renewable sources.

(ii) Characteristic patterns of energy utilisation in rural areas and the impact of energy shortages.

(iii) Characteristic patterns of energy utilisation in urban areas and the impact of energy shortages.

(iv) Comparison of calorific values of firewood, charcoal, coal, ground nut husks, coconut husks etc.

(v) An investigation of suitable collectors for photothermal conversion of solar radiation.

(vi) An investigation of possibilities of fabricating local devices for photovoltaic conversion of solar radiation.

(vii) Energy storage systems.

All and above it is very important to have proper co-ordination of research activities in Tanzania in order to avoid unnecessary duplication of efforts as well as optimise the use of the limited resources available. For this reason the Tanzania National Scientific Research Council was created by the act of Parliament in order to co-ordinate research activities, to give advice on Scientific matters as well as to promote and undertake research in any field in accordance with its priorities. Recently because of the seriousness of the energy crisis an energy Committee was created under the auspices of the Council with members drawn from institutions involved in energy research and development programme. Through this Committee a big programme has been initiated to look into the ways of alleviating the existing "energy crisis" in the Central Tanzania where the crisis is greatest. The programme is done in collaboration with other institutions.

In Table 7 we summarise the various institutions in Tanzania which are involved in energy research and development programmes.

TABLE 7: Institutions involved in Energy R and D

MINISTRIES	1. Water, Energy and Minerals 2. Natural Resources 3. Industries 4. Communications 5. Agriculture 6. Land, Urban Development and Housing 7. Prime Minister 8. National Education
PARASTATALS	1. TNSRC 2. TANESCO 3. TPDC 4. STAMICO 5. SIDO 6. UNIVERSITY 7. METEOROLOGY DEPARTMENT 8. TAMTU 9. BRU 10. UFI

REFERENCES:

1. C.M. Cipolla, The Economic history of world population, (penguin: Baltimore), (1962)

2. S.R. Nkonoki et.al, Energy Systems and development in Tanzania a paper presented at the Tanzania National Seminar on science and technology (1978)

3. A. Hassanali, Production and uses of charcoal (Mimeo), Chemistry department University of Dar es Salaam (1977)

4. E.C. Njau, Hydropower and rural electrification in East Africa, East African Academy (mimeo) (1976)

5. R. Reichel, Rural electrification in Tanzania, Faculty of Engineering University of Dar es Salaam (mimeo) (1977)

6 D.G. Pelka, R.T. Park, R. Singh, Energy from the wind, American Journal of Physics 46 (5), 495 - 498 (1978)

7. Proceedings of Workshop on Solar Energy for the villages of Tanzania, Tanzania National Scientific Research Council (1977)

8. Forest division, Ministry of Natural Resources and Tourism, Dar es Salaam (1978)

9. E.M. Lushiku, Study of selectively absorbing surfaces, M.Sc. thesis in physics, to the University of Dar es Salaam (1975)

10. R.T. Kivaisi, Selective absorbing coatings for photo thermal solar energy conversion and some useful factors in the design of flat solar collectors, M.Sc. thesis in Physics, University of Dar es Salaam (1976)

11. R.T. Kivaisi, Solar Energy near collector design, physics department, University of Dar es Salaam (1977)

12. R.T. Kivaisi, An experimental solar oven, physics department, University of Dar es Salaam (1978).

APPENDIX A 98): DEMAND FOR FUELWOOD/POLES BY 1985

REGION	DEMAND $x10^6 m^3$	POTENTIAL SUPPLY $x10^6 m^3$	REQUIRED ANNUAL PLANNING $x10^3$ Hectares
Arusha	1.88	.75	7.06
Coast	2.13	.57	9.76
Dodoma	2.12	.84	7.08
Iringa	2.53	1.41	7,00
Kigoma	1.27	0.86	2.58
Kilimanjaro	2.01	0.11	11.8
Lindi	1.17	1.17	-
Mara	1.74	0.09	10.26
Mbeya	2.37	1.62	4.72
Morogoro	1.92	1.35	3.63
Mtwara	1.87	0.26	10.08
Mwanza	3.15	0.11	18.98
Rukwa	0.99	0.99	-
Ruvuma	1.77	1.58	1.18
Shinyanga	2.74	.67	12.93
Singida	1.27	1.27	-
Tabora	2.36	2.19	1.1
Tanga	2.21	0.56	10.31
W.Lake	1.90	0.28	10.0

APPENDIX B: BIOGAS PLANTS INSTALLED BY SIDO

LOCATION	CAPACITY (Cubic metres)
Misungwi, Mwanza +	3
Ngude, Kwimba +	4
Murutunguru, Ukerewe +	3 (2 plants)
Butiama +	8
Malya, Shinyanga +	9 (3 plants)
Arusha Prison +	2
Monduli ++	4
Hanang, Arusha ++	3
Urambo, Tabora ++	4
Chamwino, Dodoma ++	3
SIDO Pavillion, Arusha x	4 4

+ Established in 1975

++ Established in 1976

x Established in 1977

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THE DEVELOPMENT OF HYDRO-ELECTRIC POWER RESOURCES IN EAST AFRICA: WITH SPECIAL REFERENCE TO KENYA

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"The large-scale generation of electricity by falling water is probably the most widespread non-oil commercial energy source in the developing countries. About 44% of non-Opec Third World electricity production comes from hydro power today. Moreover, potential capacity has barely been tapped".

- J.W. Howe, J.J. Tarrant III and J.A. Martin 1978

INTRODUCTION

With East Africa as a whole, i.e. including Kenya, Tanzania, and Uganda, no significant sources of petroleum have so far been discovered. Tanzania is, however, better placed in terms of potential energy resources, than either Kenya and Uganda, because it has proven significant coal deposits in the south and south east of the country as well as some promising finds of natural gas in the Songo Songo area of the coastal belt of the country. Both Kenya and Tanzania have extensive portions of their coastal regions floored by sedimentary rocks dating from the Mesoroic period to the Recent geological periods, which may hold some mineral oil deposits. But in the absence of any proved and immediately exploiteable petroleum resources, all these three East African countries will for the immediate future have to rely on imported oil in addition to the development of other natural resources for the production of commercial energy. Of the other sources of commercial energy available for development, hydro-electricity is for the moment, by far the most promising one, and an area which has commanded increasing attention in the last few years. This has been particularly true with the recent escalations in the price of imported oil. Prior to 1974 some comparative advantages had been found in the development of hydro-electricity as a source of large scale commercial energy as can be seen from the development of hydro-electric power stations in the Owen Falls Dam in Uganda, in the Seven Forks Project on the River Tana in Kenya and the various similar developments on the river Pangani and on the River Ruaha in mainland Tanzania. With the continued rise in the price of imported oils the relative advantages of hydro-power development in East Africa have become even more apparent and there is therefore a likelihood that a much greater effort will be made to explore the existing potential. This will be accompanied by efforts to produce firm plans for its development in the future to offset to some extent the heavy dependence on imported oil. In this paper an attempt will be made to look at the prospects for the increased reliance on hydro-electric power development in East Africa in general, and in Kenya in particular, with a view to commenting on the need to start looking at other potential sources of energy, when all the existing water power potential has been exhaused.

Table 1: TANZANIA'S EXISTING AND POTENTIAL HYDRO-ELECTRIC POWER SCHEME

River	Name of Site	Installed Capacity MW	Remarks
Pangani	Pangani Falls	17.5	Developed 1938
	Hale	21	Completed 1964
	Nyumba ya Mungu	8	Multi-purpose dam
	Moshi 1	1.16	
	Moshi 2	13.5	
	Moshi 2A	5.0	
	Binko	2.0	Power/Irrigation
	Mzimui	9.0	
	Garaya	2.0	
Wami	Pongwe	12.0	Multi-purpose 120 Max. to be developed
Hingilili	Gonja	15	
Kagera	Rusumo and Kakono	100	
Great Ruaha	Kidatu and Mtera	200	Ultimate development
Ruvu	Lower Ruvu	7.5	
	Kidunda	5.0	
Rufiji	Stigler's Gorge	500	95% firm power
	Iringa	54	
	Tosamaganga	1.4	Existing
	Mbeya	0.35	Existing
Kuwira	Sites in Mbeya Area	233	Potential
	TOTAL	1315 MW	

<u>Source:</u> Various recent development plans 1967 - 1978.

GEOGRAPHICAL CONDITIONS AND HYDRO-POWER POTENTIAL IN EAST AFRICA

The single most important source of water for hydro-electrica development in East Africa is Lake Victoria. Unfortunately for Kenya and Tanzania, most of the existing rivers flow into this lake rather than out of it, so the power potential of the waters of lake Victoria are concentrated in Uganda with the outlet from the lake in the form of the River Nile. As far back as 1952-54 the first major hydro-electric station was built at Jinja in the Owen Falls (full capacity of approximately 150MW realised in 1968) to supply power to the towns and industries in Uganda with some small amounts of power being exported to Kenya (c.30MW). The potential for further development of water power in Uganda using this one source are numerous, but they will not be discussed in this paper. Both the Kenya and Tanzanian lake regions (lake Victoria areas) are characterised by short small rivers flowing from the surrounding highlands with limited prospects for major power development. The one major exception is the River Kagera which has a large potential of up to 600MW if developed jointly by Tanzania and her two neighbouring states of Rwanda and Burundi.

As far as Kenya and Tanzania are concerned there are a limited number of rivers which rise from the highland areas and flow to the Indian Ocean and these also account for most of the potential for hydro-electric development. In this respect Tanzania with its much more extensive land area is better placed than Kenya. The total estimated potential water power resources in Kenya are only 1,000MW whereas the comparable figure for mainland Tanzania is close to 1400MW; A detailed breakdown of the main developed and potential hydro-electric power resources of Tanzania are given in Table 1.

Most of this great potential in Tanzania is still to be tapped; for apart from the small developments which are indicated in Table 1, the first major hydro-electric power station which was completed in 1975 was the Kidatu power station with a generation capacity of 100MW (Nkonoki, 1979).

The countries of East Africa are characterised by several similarities in their developments which will influence the future of hydro-power development in each case. The whole area can be said to be in a youthful stage of development with the special problems associated with this stage of development. Since Uganda has had in addition, special political problems, it has not been regarded as appropriate to discuss it in this paper. But in the case of Kenya and Tanzania, it can be seen that each country has been undergoing the rapid expansion of its infrastructure involving roads, railways telecommunications etc., as well as the improvement in general in transportation, characterised by the construction of feeder roads to reach new agricultural districts and to open up new areas of Ujamaa villages all over the mainland will mean the need for these services to supply the new nucleated settlements, which have been encouraged by the government. In addition the two countries have witnessed a slow but sure increase in industrialisation which in the past tended to be concentrated in the major urban centres like Dar es Salaam, Nairobi, Mombasa, Thika, Arusha, Mwanza etc. Such industrialisation has increased the demand for commercial energy, chiefly electricity.

In the early days, the economies of using thermal power stations as against hydro-electric power stations were carefully weighed out. Where it was more economic to use thermal stations (which burn imported oil) these were normally preferred. But since 1974 when the price of imported oil has more than quadrupled the special economic advantages and attractions of hyro-electric power are very clearly spelt out and this form of commercial energy is likely to dominate the picture for some time. It is in this context that the Kenyan case will now be examined in some detail in the rest of this paper.

HYDRO-ELECTRIC POWER DEVELOPMENT IN KENYA

A look at electricity production in Kenya over the last fifteen to twenty years shows not only the expansion in demand but even more important, it shows the shift in policy from the former heavy reliance on thermal sources to hydro-power sources. This is brought out clearly in Table 2.

With the completion of Kamburu Dam on the Tana River in 1974 hydro-electric power production in Kenya began to account for over 50 per cent of the total power generated in the country. Prior to 1975 the official policy was to develop thermal power stations to serve areas which were isolated as well as the Mombasa area which has the biggest thermal generating plant at Kipevu. But since then it has been found that hydro-electricity is a cheaper option to develop. The end result has been the construction of a series of dams on the River Tana in quick succession starting with Kamburu, in 1975, followed by Gitaru in 1978 and the Masinga Dam now under construction and likely to be commissioned in 1980/81. Despite the change in policy in favour of hydro-electricity, knowledge about the hydro-power potential in the country is still poor as can be glanced from the contradictions in estimates in the official records. For example according to the 1979 to 1983 Development Plan, the total estimated hydro-electric power potential has been put only at some 700MW with 540MW being attributed to the Tana River Basin. The explanation for the over-concentration of the hydro-electric potential of Kenya in the river Tana is brought out by a study of the flow characteristics of the main rivers in the country as shown in Table 3. A breakdown of potential power availability by drainage basin is analysed in table 4. From a study of these two tables it becomes clear that the Tana River towers above all the other rivers in the country in terms of its water capacity. However, there are many significant rivers in Western Kenya which could form the basis of smaller hyro-electric dams. The possibility of reuse of the same water to generate power at various stages of river flow should not also be ignored. As assessment based on reuse of the water of the rivers in Western Kenya could significantly raise the potential estimated capacity. Furthermore the possibility of numerous small scale generating stations (each 1-10 KW) could also significantly add to the estimated hydro-potential not only in western Kenya, but also in the Upper Tana catchment area.

Table 2: ELECTRICITY PRODUCTION IN KENYA 1958-1974

Year	Total Installed (MW)	Hydro (% of Total)
1958	82.3	31.6
1959	41.1	32.1
1960	82.3	31.6
1961	82.3	31.6
1962	100.3	25.9
1963	102.2	27.4
1964	104.4	26.8
1965	100.1	28.0
1966	113.5	24.7
1967	113.6	24.6
1968	153.0	43.4
1969	153.1	43.2
1970	153.2	44.1
1971	186.1	38.3
1972	190.8	37.4
1973	202.5	34.7
1974	266.0	50.4

Source: Various statistical Abstracts

Table 3: KENYA'S HYDRO-POWER RESOURCES (RIVERS)

Drainage Area	River	Mean annual discharge (m^3/Sec.)	Mean annual run-off 10^6 cu.m
Lake Victoria	Nzoia	60.84	1920
	Yala	30.60	965
	Nyando	15.84	500
	Sondu	39.00	1235
	Gucha) Migori)	27.56	870
	Others	57.00	1800
		230.84	7290
Rift Valley	Melawa	5.83	184.0
	Gilgil	0.89	28.0
	Molo	1.24	39.0
	Perkerra	3.96	125.0
	Others	13.62	430.0
		25.54	806.0
Athi-Tsavo	Athi	23.80	750.0
Sabaki	Tsavo	4.37	138.0
	Njoro-Lamu) Springs)	9.30	293.0
	Others	3.58	113.0
		41.05	1294.0
Tana River (at Garissa)	Tana River	148.92	4700
Ewaso Ngiro (At Archers'-Post)	Ewaso Ngiro	23.45	470.0

Source: Kenya National Atlas 1970

Table 4: THE HYDRO-POWER POTENTIAL OF THE VARIOUS CATCHMENT AREAS IN KENYA

Catchment Area	Area (km^2)	Total Potential Energy (Million kwh)
Lake Victoria catchments	51,200	7,500
Rift Valley catchments	110,592	1,900
Athi River and S.E. catchments	65,792	2,700
Tana River catchments	95,488	15,350
Ewaso Nyiro River and S.E. catchments	252,672	2,700
TOTALS	575,744	30,150

Source: Kenya Development Plan 1970-74 p.356 (Modified)

On the basis of currently available information the Tana River is not only the most promising but there has been a very determined development of its potential. There has to date been almost over concentration of the investments in hydro-electric development in the country in the Tana River Basin. To-date the installed capacity on this river is some 293 MW; prior to the completion of the Gitaru Dam, the actual output averaged 184 MW because of severe seasonal fluctuations in the available volume of water; the planned potential to be developed on this river will be 540 MW and the current estimated total potential is probably some 835 MW. Most of the developments on the Tana River are concentrated in the Seven Forks Hydro-electric Scheme which is located some 50 kilometre south of Embu Town in Eastern Kenya.

At present the estimated potential from these other rivers in the country is 230 MW and the Turkwell Gorge which is likely to be developed in the near future is 100 MW. From the above analysis it can be seen that the hydro-electric power potential in Kenya is small and could easily be exhausted in the event of rapid industrialisation. The growth in demand has been about 9% per annum and total consumption is expected to rise from 200 MW in 1976 to 352 MW in 1983. Table 5 gives the estimated sales and maximum demand of electricity for the period from 1972 to 1978. The demand is expected to continue to grow at the same rate as in previous years - though the growth in industrialisation could drastically change the picture.

Table 5: ESTIMATED SALES AND MAXIMUM DEMAND OF ELECTRICITY 1972 - 1978

Year	Total Sales (within kwh)	Maximum Demand (MW)
1972	794.8	146.0
1973	867.8	168.0
1974	971.9	186.0
1975	1108.0	212.0
1976	1207.0	232.0
1977	1316.4	253.0
1978	1434.9	274.0

Source: Kenya Statistical Abstracts

The Seven Forks Hydro-electric Scheme is to-day characterised by three major power dams already completed. The Kindaruma Dam was the first one to be constructed, and it was commissioned in 1968. This was followed by the construction of the Kamburu Dam which was commissioned in 1975 with an estimated capacity of 90MW. Finally in 1978 the Gitaru Dam was commissioned bringing the Seven Forks Project to a successful conclusion. The Gitaru Dam is likely to produce much more electricity than the first two dams in the area and its potential is likely to be in excess of 200MW. To deal with the problem of the fluctuation in the amount of power produced in the Seven Forks area because of annual and seasonal fluctuations in the availability of water, a decision was made in 1977 to construct a "high dam" at Masinga, a few kilometres upstream from the Kamburu Dam. A large lake would be created above the Masinga area to even out the water flow to the three dams downstream. In addition the Masinga Dam when completed is likely to produce another 100MW of power to add to the one from the three dams already completed. Secondly unlike the first three dams on the Tana River, the Masinga Dam would be a multi-purpose one i.e., being used for irrigation, for water storage and for the production of hydro-electricity. The Tana River System is therefore unquestionably the best surveyed river in Kenya because of its enormous potential for power in the country.

Other rivers are poorly surveyed and only a rough idea is available about their potential.

HYDRO-ELECTRICITY AND THE ENERGY PICTURE IN KENYA

Total energy production in Kenya in 1976 was estimated to be 3,800,000 tonnes of coal equivalent (of 1 tonne of wood (dry) = 0.68CE). Of this total, fuel wood used by the rural population accounted for 86.4 per cent, charcoal largely used in the urban areas accounted for 3.3 per cent; electric power both from thermal generating stations and from hydro-electric sources accounted for 10.3 per cent of total energy production. Of the total electric power produced in 1976, 54.2 per cent was from hydro electricity, the rest being generated at thermal power stations using imported crude oil. Up to the present, Kenya still relies on electricity imports from the Owen Falls Dam in Uganda. In 1976 the imports were equivalent to 91,000 tons of coal equivalent. The annual import figure is approximately equal to 30MW. Hydro-electricity can thus be said to be playing an increasingly important part in the energy scenery in Kenya. But when seen against the total energy picture the proportion of energy which still comes from firewood far outweights any other form of energy. Unfortunately most of this is what could be referred to as non-commercial energy and the estimates quoted may indeed be wide off the mark.

Turning to commercial energy, crude oil and other imported coal and coke are found to account for 89 per cent of the total. In comparison, hydro-electric power production in Kenya accounts for only 7 per cent of the total commercial energy used in the country and thermal power accounts for 4 per cent. The part played by hydro-electric power may be small in the context of the total energy picture in the country, but it is important to emphasise that it assumes a much more significant position as in terms of electric power generation. And in so far as it is one of the most important natural resource available in the country it should be given priority of attention to solve the problems of supply of commercial energy, especially electricity for industries and for urban supplies in Kenya. In so far as the current estimates of the total hydro-electric power potential in the country are based on insufficient knowledge, it should be a priority plan to improve on the state of information in this vital area of development for Kenya, by much more careful surveys. An important new source of energy for Kenya is geothermal energy. The potential is estimated at 500MW and the first producing station will be at Ol Karia in the Rift Valley in 1981. This new development will significantly complement the existing hydro-power resources'.

CONCLUSIONS:

A brief examination of the role played by hydro-electricity in Kenya and Tanzania has been discussed with naturally most of the detail being concentrated on the special problems of Kenya. The use of electricity in Kenya has expanded significantly in the last 15-20 years and there has been an important and logical start in the development of the existing hydro-electric resources of the country.

In so far as hydro-power offers one of the most widespread non-oil sources of commercial energy in the country every effort should be made to exploit all the existing potential including the possibility of using the "mini-hydro-power stations". It is clear from the study that knowledge about this resource is still scanty and it is hoped that with the increase in the price of imported crude oil and the inevitable increased reliance on hydro-electricity, every effort will be made to exploit this resource to the full along side other energy resources such as geothermal energy sources which have been shown to provide another alternative source for the country.

REFERENCES

Howe J.W., Tarrant III, J.J. Martin: North-South co-operation on energy for development, Cairo Workshop on Energy Futures for Developing Countries. (1979)

Kenya, Statistical Abstracts. Nairobi, Government Printer

Kenya, Government Printer Development Plan 1970-1974 Nairobi, Government Printer (1970)

Kenya, Kenya National Atlas. Nairobi Survey of Kenya (1970)

Kenya, Development Plan 1974-1979 Nairobi, Government Printer (1974)

Kenya, Development Plan 1979-1983 Nairobi, Government Printer (1979)

Kenya Pipeline Company, The Petroleum Industry and Energy Sector Study - prepared by Mase Economic Services Ltd. (1978)

Nkononki S, Energy Systems and rural industrialisation in Tanzania. Paper presented at the Workshop on Industrialisation and Rural Development, Arusha 4 - 6th April (1979)

Tanzania, Five Year Development Plan 1969 - 1974 Vol. 1 General Analysis. Dar-es-Salaam. Government Printer. (1974)

ENVIRONMENTAL RESEARCH AND ITS APPLICATIONS FOR ENERGY IN TRADITIONAL SOCIETIES

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INTRODUCTION

Levels of energy demand and economic development are intimately related although the relationship is not a simple, unilinear function. Successful development planning must, however, consider the increased demand for energy which accompanies increases in productive capacity. The focus of such planning is usually industrial consumption, a consumption that is largely satisfied from conventional fossil fuel sources. Such a focus in Eastern Africa necessarily raises issues of scarcity of fossil fuel endowment, oil dependency and consequent balance of payment problems casting discussion in terms of commodity flows to the modern sectors of the economy but neglecting the major issue of household energy consumption. It is necessary to critically review the policy towards energy demand in Eastern Africa, placing emphasis upon household energy consumption.

Underlying this review must be an understanding that fuel, like food, is a basic human need. Although, in a global sense, sufficient fuel resources exist, the conditions of poverty in Eastern Africa, from personal to national level, result in an energy crisis. This crisis particularly strikes the urban and rural poor, compounding difficulties for development planning. Yet unless planning is directed towards the energy problems of Eastern Africa, poverty will persist and the process of underdevelopment will be entrenched.

Existing Commercial Energy Sources

A summary analysis of existing commercial energy sources in Eastern Africa points to the following conclusions :

(a) In comparative terms, the fossil fuel resources of Eastern Africa are poor;

(b) In comparative terms, the non-fossil fuel resources of Eastern Africa are poor;

(c) It is comparatively expensive to bring on line, non-fossil fuel production and, therefore, fossil fuel technologies are preferred. Consequently, there is a serious dependency relationship, reflected in negative balance of payments, in most economies since fossil fuel is imported.

(d) The poverty of energy resource base means that other material, chiefly organic material, becomes the major energy source available to the majority of the population.

High Technology Transfer

In considering the present and projected energy shortfalls, it is necessary to raise the question of technical innovation. Given the existing technology, is it possible to bridge this energy gap? Such a question can be considered in both a qualitative and quantitative manner. The qualitative appraisal would point to the history of failure that marks attempts to transfer technology from developed to underdeveloped countries. Existing nuclear, hydroelectric, geothermal, and even appropriate technologies are transferred with difficulty. But, the complex arguments about qualitative change need not even be considered at the moment - the quantitative problem is immense. Even if nuclear technologies could be brought immediately on line, energy shortfalls would exist in Eastern Africa beyond the year 2000.

Appropriate Technology

As planners begin to realize that fuelwood and charcoal will be increasingly important to the Eastern African economies, attention is increasingly focused on renewable resources and alternative technologies. Much has been written recently about the feasibility of such technologies. The four major types of alternative technologies for renewable resources are :

(a) Solar Energy

(b) Bioconversion

(c) Water Energy

and (d) Wind Energy

The National Academy of Sciences (1976), having considered these technologies, offered the following "fundamental and inescapable conclusions" (p. 11):

1. A variety of energy sources and technologies is indeed available as alternatives to conventional power systems;

2. With the exception of a few devices (e.g. homemade windmills, solar dryers) there are not cheap alternative technologies of significance for either industrialized or developing nations, and there will not be any in the near future;

3. It is not enough that an energy source be available; the technology to put it to use must also be available. The benefits of any one of the suggested alternatives for producing energy could be multiplied many times if even a small amount of capital were invested (a) in developing a technology needed to use the energy and (b) in ensuring that technology is properly integrated into the economy and culture.

and again, (p.4):

> In short, the developing countries, like the rest of the world, seem condemned to a continuing struggle with increasingly high relative prices for energy from conventional sources. The "energy crisis" will continue to be, in essence, a fossil fuel crisis (specifically, an oil crisis).

An Energy Scenario

A realistic energy scenario for Eastern Africa would indicate that neither increasing existing use of commercial sources, transferring high technology nor developing appropriate technology would have an impact on the energy crisis. Woodfuel will continue to be increasingly utilized. A temporary phase of increased dung and crop residue utilization will likely occur, because the labour required in making such briquettes is less than that required for charcoal. Such energy practice is, however, more common to Asia than Eastern Africa. Dung and cro p residue are also needed to complete the nitrogen cycle, a necessity for agricultural production, so that their use as a fuel has a high opportunity cost. Charcoal will rapidly rise to the fore, but, by that time, the extent of deforestation will be apparent.

Paralleling deforestation, and the consequent environmental degradation is the reduced access to forest resources resulting from changes in land tenure. These processes have a constraining effect on development particularly as the demand for woodfuel increases (due to increasing population and the existing favourable price differentials). In broad outline, two solutions may be envisaged, namely, energy substitution, or an increase in woodfuel resources. The former necessitates large capital investment (Diagram 1), while the latter requires structural changes in the organization of production, especially changes in legislation. Yet the latter scenario is a more probable strategy, given the large level of investment which energy substitution would require, and, assuming even with other forms of energy substitution, total consumption of firewood will increase by twenty per cent between 1970 and 1980 (Earl, 1975).

SUMMARY AND RECOMMENDATIONS

The current energy shortfalls that impact globally have a differential impact between the developed and underdeveloped countries. No technological fix is currently available that would rapidly transform the energy budget of the world. For the next two generations, the world will essentially be a fossil fuel economy. In underdeveloped countrie s, where increasing population and increasing urbanization are raising the levels of fuel demand, use of woodfuel resource will increase absolutely. At the present time, woodfuel is the cheapest and most readily available form of energy to the poor. Damage to ecosystems will result unless careful planning accommodates this increased demand for woodfuel.

Growing demand for woodfuel occurs as access to forest resources decreases for the majority of the underdeveloped populations. Subsistence producers who rely on "free" access to the forest are thus further impoverished. Ecological degradation occurs but the solution to environmental impact lies within redefinition of the socio-economic framework in association with engineering or forestry schemes. People need energy; people need wood. Planning must focus on both wood production and ecological conservation.

Project design of forestry development is fraught with difficulty. Problems are particularly acute because although selection options for project type, species, and site can be outlined, the determining factor in forestry projects is project purposes, i.e. conservation or production orientations. While emphasis should be placed upon production projects, capital to finance such projects is frequently scarce because of the high opportunity cost of such projects in the face of capital shortage. Without such projects, however, the energy crisis, especially in underdeveloped rural and peri-urban areas, will escalate. Only with sincere commitment from government to development in rural areas will forestry projects be speedily implemented, thereby easing the impending energy crisis among the poor.

Expanding existing commercial energy sources, transferring high technology and even utilizing existing low technologies will not substantially ameliorate the energy crisis in the short term. It is therefore necessary to develop forestry projects with other elements of factor supply in integrated development projects. The commitment to the development of productive forestry projects will probably focus upon small scale programs if the rural and peri-urban poor are to benefit. The most feasible option for projects for fuelwood production would seem to be village woodlots, a project design that would not only reduce environmental degradation but would have a significant employment generating function.

Simultaneously to the emphasis on increased wood production, it is important that three complementary technologies be rapidly developed or improved, namely :

(a) wood stoves for household use;

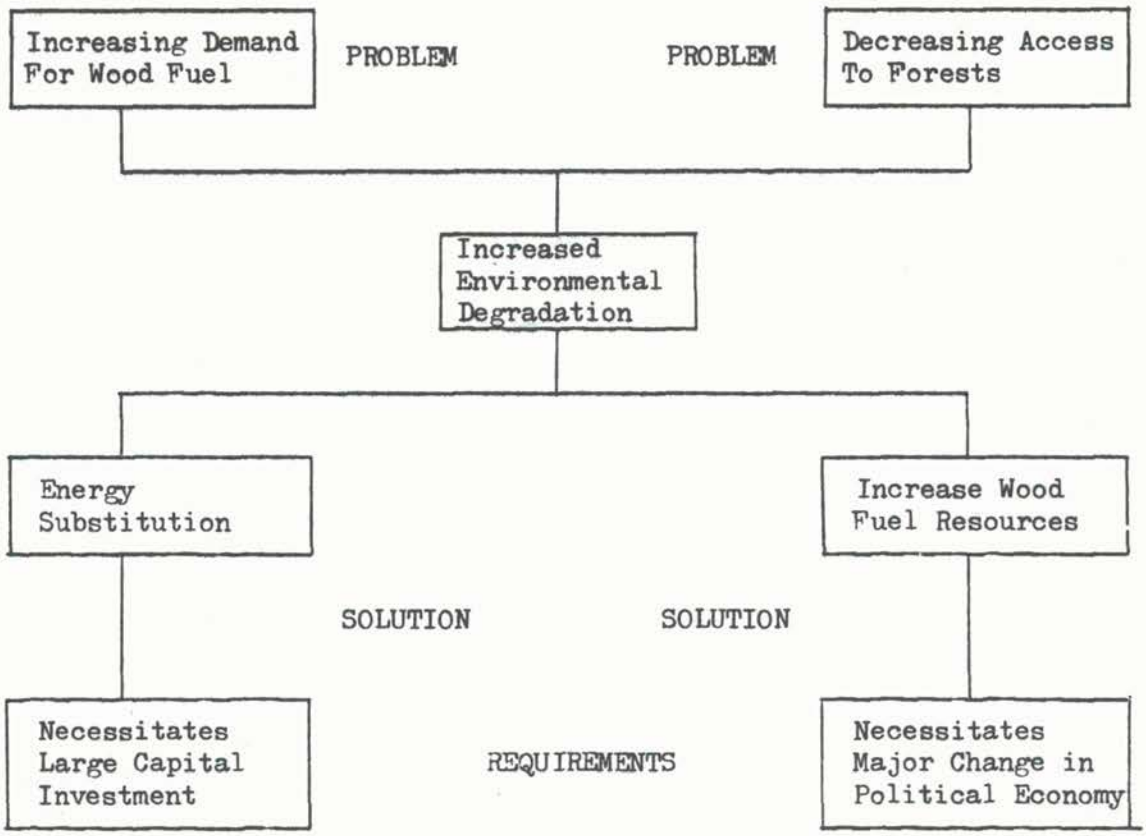
(b) insulation methods where fire is used for warmth;

(c) more efficient charcoal converters, such as the pyrolitic conversion technique.

Monies employed in the development of these technologies will enhance the efficiency of woodfuel utilization and thus reduce the rate of forest depletion.

DIAGRAM 1

CONTRADICTIONS IN THE AFRICAN FUEL CRISIS



REFERENCES

Earl, D.E. 1975. Forest Energy and Economic Development, Clarendon Press, Oxford.

National Academy of Sciences 1976. "Energy for Rural Development" Renewable Resources and Alternative Technologies for Developing Countries, Washington, D.C.

RURAL ENERGY DEMAND, PERSPECTIVE AND PROSPECTS

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SUMMARY

The level of a nation's development is directly proportional to the mean national energy per capita. To monitor this accurately by presupposes that the gross national energy consumption is measurable. In the developing countries of Africa, like Kenya, a majority of the people live in the rural areas and almost entirely depend on firewood and other vegetable materials whose energy capacity has not been measured and may not for sometime to come be accurately quantified. However, the adverse environmental effects e.g. the enhancement of aridity and desertification are measurable and causing concern in many countries and alarm in others. The question is raised as to how the rate of development in real terms can be determined or planned in these countries? To be able to give a balanced view of the perspectives and prospects of energy demand in Kenya's Semi-Arid rural areas, it is deemed necessary that ways and means of more accurately quantifying per capita energy consumption and therefore energy needs of the country to meet predetermined targets must be found through intensive and extensive energy research. The initial step in this effort seems to be the collecting of already available information and putting it to practical use in order to avoid the unnecessary and expensive duplication of effort which may already have been covered. To achieve this goal, very close co-operation should be encouraged between the national energy authorities and institutions of higher learning and research in each country.

This paper attempts to suggest that to meet the minimum future environmental requirements, a deliberate movement away from the traditional dependence on firewood as the major source of energy in semi-arid areas of Africa must be achieved relatively quickly. Failure to meet this objective would tend to intensify and further aggravate the adverse environmental effects already acknowledged.

It is gratifying to note that the concept of "one planet earth" is increasingly becoming more accepted - a fact which leads one to the hope; and indeed to the expectation that the necessary funding on the overall question of energy demand, needs perspective and prospects will be looked upon as a critical joint issue facing humanity and therefore collectively accepted as a subject that has a direct bearing to the very survival of mankind on this earth to which solutions must be found. In this paper concern is expressed at the continuing tendency by the developed countries and therefore the holders of an assortment of technologies in this and other sectors, to wish to hold onto and therefore control the mechanisms of harnessing and conveying energy to places where the demand is.

This paper also suggests that the apparent solution to the energy crisis must in the final practical application be inexpensive and readily available to the majorities in the world with the least or no incomes at all. The solution is therefore seen to be in the abundant sources of solar, wind and natural gas in all its forms. At some stage in this paper, it is suggested that nuclear energy must at this stage and for a long time to come be seen and deemed to be irrelevant and in any case environmentally unacceptable and economically too expensive for a majority of the residents in the rural areas of the world with specific reference to the social situation prevailing in the arid and semi-arid zones of East Africa.

INTRODUCTION

Energy Consumption and Demand patterns of Kenya and many other African countries are inevitably based on electricity, however it may be generated.

Many of our countries are not endowed with large riverss and water falls for the generation of hydro-electric power or with fossil fuels and natural gas. Even in cases where water is available, large quantities of water are arrested from other activities e.g. domestic and agricultural, for the purpose of generating electricity.

The hydro-electric generators and the technology of harnessing this energy resource is patented and held by a limited number of countries thereby making water not what one may call a cheap source of energy for countries that do generate it.

The patterns of utilizing available energy have unfortunately been developed and organized along the lines of controlled supply. It is available to the richer members of the community at a high price. However, to consider the futures of energy and environment, one has to look at the history of the subject within the context of the people s inhabiting semi-arid Africa and as a special case, Kenya. It becomes immediately apparent that in the past Kenya has not operated on an explicitely stated energy policy neither has she established an institutional framework within which to determine targets and endeavour to achieve them. A deliberate energy policy has yet to be published and it would appear relevant for a National Authority to be established to take charge of this important national issue.

The Need for Long-Term National Policies on Energy

The countries of Africa inherited from the colonial powers a "laissez-faire" system of handling basic natural resources. This state of affairs was later complicated by a diversity in the land tenure systems. There were, and still are free-hold lands, Trust lands and Government lands; within which the energy resources to be discussed are found.

In the case of Kenya, Freehold lands are in every case as their name suggests; while Trust lands belong to people of specific ethnic groups and whose right to the land is held in trust for them by their respective local authorities or their equivalents (commissions etc.) To a large extent, government lands have had no effective authority to police them and have to a large extent been plundered of their basic natural resources - be these forests or minerals. This loose set up did not only apply to Kenya but was more widespread in Africa.

With this background, it is not surprising that effective control has not been exercised by the governments nor have many of them developed effective policies on the use and conservation of their major energy resources including water, vegetation (forests), geothermal or fossil fuels.

The laissez-faire approach to things permmeated the entire fabric of life. Multi-national companies were allowed to import and distribute fossil fuels and natural gas while at the same time exporting large quantities of timber and other wood products. In the early days, most of Africa received refined fuels and missed out on the development of the petro-chemical industries and the high employment element associated with this activity. Many people who would have been trained and absorbed in the labour force of the petro-chemical industries remained in the rural areas of each country conducting an object subsistance way of life. This was a sure way of keeping down the mean energy per capita. However, the point I wish to emphasize here is the drifting away and the widening gap between the oil producing and exporting countries and the Western based multi-national companies; with the result that the consumer countries which depend on this type of intermediary arrangement will increasingly find themselves highly disadvantaged and indeed sitting at the end of a very rough stick! Since I maintain that the level of any nation's development is directly proportional to the national mean energy per capita the arrangements outlined above cannot consciously continue to be suffered in Africa.

Recently Kenya found herself starved of aviation fuel and the public reacted angrily at the lack of firm government control or the presence of a national machinery that would assure or guarantee in effect, the long term supply of this commodity at genuinely reasonable prices. I discuss these matters at length because the rural masses, who are least prepared for major shocks continuously find themselves to be the receivers of the end results of such omissions. Kenya's next 5 year development plan which emphasizes rural development assumes greater significance when it is read against this background. The plan will have to ensure a higher national energy per capita before its objective of alleviating poverty is achieved.

I venture to suggest here that it is not too late for Kenya or a consortium of African countries to consider as a matter of urgency the formation of a fleet of tankers totally owned by this consortium and completely free of multinational company influence. The Consortium would have a greater chance of reaching a reasonably cheaper long term arrangement of guaranteed "crude" in a world of diminishing supply and rocketing prices.

As the Kenya aviation fuel disaster has shown us, the act of leaving the control of energy resources in the hands of multi-nationals is dangerous in the extreme to the stability of developing nations.

In Kenya we witnessed the near disruption of the tourist industry a fact which signals the real possibility of lack of fuel or indeed the crude itself drying up some day, which would totally ruin the national economic structure. The multi-national companies would retreat to the capitals of their parent organizations without too much remorseabout the disappearance of the effective - status of nationhood or sovereignty of the countries concerned. This eventuality cannot be accepted and alternatives to the existing arrangements should be accorded the priority of national security or survival. In all these matters, the rural masses stand to have the worst end of the deal and the situation promises to worsen as far as the availability and pricing of this source of energy is concerned. The question at hand is, will Kenya decide to let the matter take its own course?

The trend in production of this energy resource will increasingly come under the direct control of the producer countries. If one could confirm that "national" tankers would more than create the necessary assurance to the producer countries that their bilateral arrangements with the consumers of their product would not be torpedoed by third party companies to other destinations, the prospect of greater accommodation in matters of supply and pricing would loom on the horizon as a possible reality. Since the prospects of realizing this goal holds aspects of greater prosperity for the rural areas of Africa, one can only suggest the establishment of continuing dialogue on the matter.

The Kenyan Case Review and Beyond:

The people of Kenya and the respective institutions that have been established in the country have independently considered their energy needs and have gone ahead to devise ways and means of acquiring the same, initially at the subsistance level. Like any other developing country, over 95 per cent of Kenya's population derives most its energy from vegetation, either in a direct form (firewood) or in a partially converted form (charcoal). This has in effect, meant the extensive harvest of trees and shrubs for use as firewood or their conversion into charcoal, which is in turn burned to produce heat and a low grade of light. Rarely is firewood burned to produce electricity.

At the turn of this century, Kenya's low population density and the consequent low demand on the country's vegetative cover did not appear to cause any major questions. As the human population has progressively increased and its demand for firewood intensified, the adverse effects of the removal of vegetation to supply firewood has been felt in a number of areas crucial to the very existence of a series of viable natural systems. Watercatchment areas have been destroyed; rain patterns have been changed and with this, the geography of the respective regions in the country are believed to have been altered, may be permanently. A good example of a changed climate is that of the Savannahs of Africa which are steadily being turned into arid zones and assuring the definite expansion of the Sahara desert. While attempts have been made by crude methods to produce charcoal for the urban populations, wild fires have resulted and destroyed large areas of natural vegetation and thereby brought about environmental degradation. It is at this point of uncontrolled destruction that one hopes for a serious attempt by governments to move towards greater environmental protection.

In the case of Kenya the worst affected areas may be found on lands whose legal status is either "Government land" or that of "Trust Land". Although the offices of the Commissioner of Lands and those of the County Councils are vested with the authority to look after these lands respectively, it is common knowledge that neither of these two authorities has at its disposal a law enforcement mechanism for ensuring the proper policing of these lands, neither have they the necessary competence for ensuring the proper conservation or utilization of the resources to be found in or over them.

The other glaring omission that is immediately apparent to the casual observer is the lack of dependable statistics relating to the rate we are consuming the available wood in Kenya - a fact which would provide the Forestry Department with a vital baseline showing the effort needed for re-afforestation or afforestation required to (a) contain the vegatative erosion that is threatening the country with desertification. (b) turn the scale from that of :diminishing vegetation to that of increasing forests and green cover in general. The effort one sees in Kenya is that of systematic displacement of natural tropical woodlands with exotic forests, mainly of pines and gum trees. The specific question here is whether the Kenya Government has a stated policy in this important area of vegetation propagation? With over 95 per cent of Kenyans depending on wood or wood products for their major source of energy, can the government afford to remain silent on the issue? If there is a declared policy in this area, are the policy instruments adequate to meet national needs? Or should the government not make public its approach towards resolving this issue and allow the general public to become willing participants in the implementation of the mechanisms geared towards finding real solutions?

<u>One Approach</u>:

The type of information we need to have is along the following lines:

The population of Kenya is approximately 15 million. It takes (say) 15 cu. yds. or 45 cu.ft. of wood to sustain one person per year

It will take 45 x
15
450
225
675 million cu. ft. of wood to sustain Kenyans per year.

Then one needs technical information based on many years of research and expert observation indicating what trees grow in the various climatic zones of the country and how long it takes to grow 1 cu. yd. or 9 cu. ft. of wood and consequently how much national effort is required to produce the needed 675 million cubic feet of wood per annum putting into account the annual population growth and an element of excess tree production to secure a growth that will ensure an expanding green belt in the country. The other question that needs to be answered is: how many years in advance of utilization is the planned afforestation programme to be initiated to yield positive results? Assuming that it takes up to 10 years under average climatic conditions to produce 9 cu.ft. of wood from one seedling - the planners would have to come up with a "bridging strategy" which would ensure continuity of life in the rural areas while the above scheme progresses to maturity. The services of economists would have to be enlisted to indicate the cost of this effort right from the growing of seedlings, their distribution etc. and finally their harvest and use. Socialogists and educators would have to give guidance on how to enlist maximum community participation in the scheme to make it work.

With respect to the bridging strategy, one would have to think of a practical approach to this issue. Since we are considering semi-arid zones of Africa, reclaimed land should be planted with food (protein) producing annual and perennial leguminous shrubs e.g. soya beans etc. which would help the soil by way of nitrogen fixing; and at the same time produce high protein yielding food and a good volume of combustible fuel. This bridging strategy may have to be continued for many years thereby saving substantial cubic feet of living woodlands and thereby ensure the expansion of the greenbelt and substantially reduce the effects of desertification.

Environmental Improvement Projects:

An aerial view of Kenya suggests that literally millions of small catchment dams could be built all over the country under National Service Schemes. The objective of such schemes would have to be seen to be multiple. Through the national service schemes , the problem of unemployment would be tackled. Through the catchment dams, the major objective would be the slowing down of rainfall runoff with the intent of facilitating greater seepage and the consequent pasture improvement and better woodland growth. In this way natural plant successions would be triggered off in areas that may otherwise have been devastated through overgrazing; soil erosion, burning etc.

Public Demands:

The current discussion in Kenya (at the parliamentary level - March/April 1979) surrounds the crushing demand by the House for the government to effect its plan for a cheap "Rural Electrification" programme.

In this political discussion, the unrealistic assumption that rural incomes will afford what parliamenterians term as "cheap electricity" is extremely false. Within the context of the present high cost of living and the wild inflationary trends that no one seems capable of taming, it is a major effort for an average rural family without an "external" source of income (from members of the family working in the towns) to afford the purchase price of a litre of kerosine for lighting on a regular basis! How is that same community going to afford rural electricity? However, the foregoing comments not withstanding, it is heartening to note that the demand for an alternative source of energy in the rural areas of Kenya has been recognized by the peoples's representatives. The only problem is that they are over-emphasizing the most known and readily available source of energy which, superficially, appears to them to hold the answers. One would have appealed to the decision makers at Parliament to call for the formation of a National Energy Authority, vote substantial funds to it and charge it with the responsibility "to deliver the goods", in the same way a Water Development Ministry was recently created in the country. An approach of this nature is expected to receive general acceptance in government circles where the idea of setting up an energy authority has been under consideration for some time now. One cannot deny that the demand for cheap electric power in the rural areas is a high hope in the minds of many rural residents.

When one thinks about the question of small hydro-electric plants which would effectively operate on smaller rivers and serve small rural communities, the question of capital outlay, continuing operating expenses and the manpower to run the plants remain unanswered. Rising by frightful progression, the cost of liquid petroleum fuels is rapidly getting to a point where it will become virtually impossible for a majority of developing countries to sustain viable economies. The same applies to natural gas. This state of affairs could be a blessing in disguise provided it spurs those affected into fruitful activity in searching for alternatives.

Looking at East Africa, the traditional suppliers of technology, even in the energy field were the former colonial powers who, for lack of basic knowledge did not appreciably develop adequate mechanisms for harnessing geothermal power which geologists have pronounced to be in plenty supply in the volcanic zones in which East Africa happens to be geographically located. Alternatively, these powers might have planned this omission or else it was an accident brought about by easy access to cheap petroleum. The politics of the silence which prevailed over a major energy source in E. Africa reveal the fear the colonial powers must have had to grant economic control and independence in these matters to the developing countries concerned from the very start. Was the element of continued dependence a major factor in decision making then? Energy independence like political independence is a question of self-determination against many odds. This is another reason why an energy authority would be well placed to guide the governments of East Africa in formulating sound energy policies for viable futures.

Recognizing the fact that East Africa has a very strong agricultural base, the possibility for alcohol based fuels being manufactured from farmed cereals is very high although it has not seriously been planned. The starch producing plants stand out clearly in this equation, provided that distinct government policies are enunciated to that effect and the respective commodity prices are reasonable enough to provide a natural incentive for extensive production by the farming community.

Other energy resources freely available to East Africa, and so in the arid and semi-arid areas include direct solar energy and wind.

The development of these two sources of energy has been slow because the developed nations have not yet succeeded in determining how best they would be able to control this source of energy. At the time of writing this paper (1979), most people make reference to the "Solar cell" as the way of harnessing solar energy. This paper attempts to suggest that the question of efficiently harnessing, using and storing solar energy has hardly been touched by the world researchers - and should be given priority funding by all countries. There must be better ways of utilizing solar energy that would be more environmentally acceptable than the solar cell. This is a specific task for our researchers.

One should also say that much parallel research has already been undertaken in this area and it would serve a very useful purpose were the research results in the field to be widely and freely publishe d to be shared beyond sovereign, economic and political boundaries in the world with the relevant technology being purchased through the Science and Technology Division of the United Nations. The release of technology could also be enhanced and facilitated at the bilateral level.

Wind Energy:

American scientists have been working on how best to utilize Wind Energy as a natural asset to the peoples of the world. Their research in this area has confirmed that wind is blowing at some point within a radius of 100 miles of any given point on the face of the earth. They have further determined that any household in the world is capable of harvesting more wind energy than it is capable of utilizing. Supposing then that the harvested energy were harnessed, measured and subscribed into a nationally connected grid which could be regulated within a nationally controlled system. The excess wind energy could build up credit for a majority of the rural households, and directly help to improve their way of life after supplying them with their own freely generated power. The surplus energy from the rural areas would go to industrial and other national activities without the least impairment t o the environment.

Geothermal Energy:

The trusting attitude adopted by many Governments that in a free market situation, the natural laws of supply and demand would always b e operative has not always been correct. In Kenya, this fallacy has been demonstrated as far as aviation fuel is concerned. Kenya believed that, motivated by a government protected monopoly and assured profits, a certain oil company would always supply the needed aviation fuel. When the aviation fuel supplies from Iran dried up for a while recently, the eventuality almost wrecked the multi-million pound Tourist Industry. The message got home. For National Survival, a long term dynamic energy policy is necessary. How Kenya acts from this point is quite vital to her future stability as a Nation; because the abudance of energy and the stability of supply of that energy is an accurate measure of any Nations' economic strength and consequently its ability of sustaining social and political stability. Naturally, these two basic prerequisites are amongst the qualities we hope to achieve for our country Kenya. With respect to Geothermal energy, Geophysicists indicate that Kenya's potential may be higher than her hydro-electric energy. If this be the case, the question that arises is : where did the change in our developmental emphasis occur to the extent that our Geothermal energy resources remain completely undeveloped and therefore unavailable to our National developmental process including the very basic energy demands in the urban and rural areas of the country. Due credit must be given to the government of Kenya for its initiative and foresight in requesting for UN assistance and expertise in the field of exploring, distribution and the extent to which geothermal energy may augment Kenya's national energy needs. One has to acknowledge the fact that the limited preliminary work undertaken on this scheme can only serve as an indicator to future expectations. Additionally one has to hope that appropriate legislation will be enacted in Kenya soon vesting all geothermal resources in the state and going to the extent of setting up regulations for its exploitation conservation and cost to the consumers.

Other Fuels:

In considering the demands and supply of energy to the rural areas the question of isolated settlements and distances over which the commodity is to be transported to the consumers becomes very real. It is at this point that the solar and wind energy resources become extremely attractive because they are right there at the consumer's doorstep and the real question is how to make them available to that consumer on a continuing basis at a price he/she can afford. Until this question is answered, the original energy problem will still remain with us. It is in this direction of a freely available and inexhaustible source of energy that the developing countries and indeed all humanity should direct their research funding. At the present time, a majority of th e developing countries which may be interested in solar and wind energy do not have to spend large sums of money to start their search from scratch. Much information on this subject is available. This paper therefore suggests that in areas where both the information and the technology for utilizing solar and wind resources are not freely available, the UN and Regional Organizations like OAU should give serious consideration to the purchase of such information and make it freely available to the world community in need of it. This issue also reveals areas of cooperation for mutual advantage both in research and utilization and energy conservation. The tunnalization of solar energy by the direct reference to "solar cells" should be abandoned and the issue tackled by African countries from a broader base.

Nuclear Energy:

For purposes of demand and supply in the rural areas of East Africa, this source of energy is not only too expensive, too highly controlled, highly dangerous as a lethal environmental pollutant (see the Harrisville, USA case) but I dare call it simply as being out of the way and virtually irrelevant at this stage in time. I am stating this point of view deliberately because I can't see a sane reason for an East African developing country contemplating the installation of a nuclear power plant before and until it has tapped and exhausted the other freely available and clean sources of energy. I must however, say that, at some remote future date, this source of energy could become easily available to many households in the world when safer approaches to the question of nuclear energy exist - but this source will always remain subject to debate.

Other Initiatives:

During the month of March 1979 a two-day seminar was organized in Nairobi by the Japan Trade Centre in conjunction with Kenya's Ministry of Natur al Resources to discuss the exploration and development of Kenya's Geothermal energy resources. On this occasion, a government representative was quoted as saying that the government had already started developing a geothermal power plant at Olkaria, near Naivasha, which would generate 15 megawatts. The same representative was further quoted as saying that the government intended to develop other potential zones which have been located in the Rift Vally to supplement the present supplies of electricity.

These declarations go a long way in creating an atmosphere of confidence in the government's effort to achieve a greater degree of self-reliance in the field of energy by its practical approach in trying to put to full use the energy resources available in Kenya.

In conclusion, one can only say that Kenya stands to better utilize these resources and develop better long term energy policies subsequent to the setting up of a National Energy Authority with a clear mandate and a budget to explore every aspect of the energy question.

AN INVESTIGATION OF SOLAR ENERGY DISTRIBUTION IN EAST AFRICA - THE CASE OF KENYA

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SUMMARY

This paper presents the solar radiation data by making a mathematical model and simulation of solar insolation for East Africa. The resulting equations are rather complex and are, therefore, solved by a computer program using known atmospheric and geographical data from Kenya as a test case. The computed results are then compared with the measured solar insolation data for eleven stations in different locations of Kenya. This mathematical model which was first proposed and used at Ege University gives satisfactory results with the least amount of input variables. With the aid of another computer program, the two sets of data are compared with those obtained from one of the well-known correlations, the "Universal" formula. It is found that the "Ege" model gives a better correlation than the "Universal" formula and therefore could be used, with little improvement, to obtain reliable solar maps of all the East African countries.

INTRODUCTION

The energy demand of many developing countries of Asia, Latin America and Africa can, partly, be met by the technically and commercially attractive applications of solar energy. This is more so since the conventional energy resources, the fossil fuels, are undergoing a fast depletion. It is currently evident that the conventional energy resources will be out of economical use within a century because of the ever increasing energy consumption and the limited fossil fuel reserves in the world. Moreover, the cost of exploration production and transportation of fossil fuels (oil, gas, coal) is bound to be so high as to render the use of these energy resources prohibitive. It is, therefore, imperative that there be urgent search into a transition from conventional to non-conventional energy resources in not too distant a future and solar energy is one such resource.

Solar energy has the advantages of being in abundance, undepletable and free of pollution. It can be stored by converting it into other useful forms of energy albeit the conversion efficiency is still rather low. Its main disadvantages, however, are its low intensity, intermittent characteristics, low distribution throughout the globe and the present high cost of tapping it compared with the conventional resources. The knowledge of solar radiation distribution is a vital prerequisite for the design, manufacture and testing of any equipment meant for utilization of solar power. The first step therefore in application of new technologies utilizing this energy source economically is to map out its intensity throughout the year. Quite a good deal of theoretical ways for determination of solar insolation (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11) have been suggested since the world seriously turned its attention to this non-conventional energy resource. Reliable solar insolation data can be obtained by monitoring and continuous recording of total, direct and diffused components of solar radiation. This, however, is a rather costly operation, and none of the solar energy rich developing countries of East Africa has complete facilities to fulfil the operation. In Kenya, particularly, there is at present only one location which is equipped with appropriate solarimeter. A few stations in this country are equipped with Gunn Bellani Radiation integrators. Theoretical prediction of solar insolation for East Africa, and Kenya in particular, is thus necessary to complement and counter-check the measured data.

In this paper we present a method for determination of solar insolation in East Africa. The method is then applied to eleven locations (stations) in Kenya where reliable insolation data have been measured. The method is executed as follows: Equations for estimating solar insolation on a horizontal surface on any location on the earth are reviewed. A computer program for solving these equations are run using appropriate input data for the eleven stations in Kenya where rather detailed solar data were measured. The computed results are then corrected for the mean sunshine hours per day for a whole year. The resulting data are then charted out on a Kenya map in comparison with the actual measured data as well as those computed using the "Universal" formula (9).

THEORY

The total amount of solar radiation reaching any site on the surface of the world (Q_t) is the summation of direct (Q_d), diffuse (Q_{dif}) and reflected (Q_r) components of solar insolation given by

$$Q_t = Q_d + Q_{dif} + Q_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1).$$

The diffuse radiation is always present but the computation of its exact value is not always possible. The reflected solar radiation from the ground also does always exist but its computation is not also possible in all cases. The derivations and formulations for the determination of the values of the diffuse and reflected components of solar insolation are given by Robinson (10). The main constituent of total solar radiation is, however, the direct component Q_d which can be obtained from:

$$Q_d = A_0 I_{sc} \tau^m \cos(B) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where A_0 – correction factor for the solar constant.

I_{sc} – solar constant (The standard value of the solar constant proposed by Thakaekera and Drummond (1971) is $1353\ w/m^2 = 1.94\ cal/cm^2\ min = 428\ Btu/ft^2\ hr = 4871\ kJ/m^2\ hr = 1.94\ ly.min^{-1}$) (1)

B – the angle of incidence of direct radiation.

τ – atmospheric transmission factor.

m – air mass (angle between the zenith and the sun).

The cosine of the beam's angle of incidence (cos(B)) is a function of several variables and its relation to these variables can be determined by the following formulation:

The unit vector normal to the plane in question is:

$$\bar{n} = \begin{cases} x_n = \sin(w).\cos(T) \\ y_n = \sin(w).\sin(T) \\ z_n = \cos(w) \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The vector representing the solar beam is a function declination, d, hour angle, S, and the latitude, P:

$$\bar{r} = \begin{cases} x_r = \cos(d).\sin(S) \\ y_r = \cos(d).\cos(S).\sin(P) - \sin(d)\cos(P) \\ z_r = \cos(d).\cos(S)\ (P) + \sin(d)\sin(P) \end{cases} \quad \ldots\ldots\ldots (4)$$

The hour angle, S, is given by (14):

$$S = t' - a = t + (t+24N)C + G_o + (1+C)\Delta(\psi) - \frac{\psi}{15} - \alpha \quad \ldots\ldots\ldots (5)$$

where t' - star time
t - regional time
N - number of the day of the year
C - constant having the value of 0.002737790931
G_o - Greenwich star time
ψ - Longitude of the location
$\Delta\psi$ - hour interval of the location
α - A constant (obtainable from Neutical Almanac) (15).

Greenwich time G_o is calculated from:

$$G_o = 6^h 37^{min} 05.893^{sec} + 236.55536(Y - 1974).365 \quad \ldots\ldots (6)$$

where Y^o is the A.D. year.

The scalar multiplication of vectors $\bar{n}$ and $\bar{r}$ gives:

$$\begin{aligned} \cos(B) &= (x_n x_r) + (y_n y_r) + (z_n z_r) \\ &= \cos(d).\sin(S).\sin(w).\cos(T) + (\cos(d)\cos(S)\sin(P) - \\ &\quad \sin(d)\cos(P)\sin(w)\sin(T) + (\cos(d)\cos(S)\cos(P) + \\ &\quad \sin(d)\sin(P)\cos(w) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7). \end{aligned}$$

The total transmission factor of the atmosphere, , to be used in Eq.2 is a function of the wavelength of the radiation and is computed by:

$$\tau(\lambda) = \tau_h(\lambda)\ \tau_d(\lambda)\ \tau_s(\lambda).\ \tau_{o_3}(\lambda)\ \tau_{sa}(\lambda) \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where τ_h, τ_d and τ_s are scattering of beam radiation due to air molecules, dust particles and water vapour molecules respectively. τ_{o_3} and τ_{sa} are the respective ozone and water vapour absorptions (For a detailed discussion of these variables see, for example, Beba et. al., (13)). The air mass, m, previously defined in Eq.2 is given by the following equation:-

$$m = 1/(\cos(d)\cos(p)\cos(S) + \sin(d)\sin(P)) \quad \ldots\ldots\ldots\ldots (9).$$

The solar constant, I_{sc}, which varies monthly is a function of wavelength, and can be written as

$$I_{sc} = \int_o^{\infty} E(\lambda).d\lambda \quad \ldots\ldots\ldots\ldots\ldots (10)$$

where $E(\lambda)$ is the energy density. Equations (2) and (10) give:

$$Q_d = A_0\cos(B) \int_o^{\infty} E(\lambda)\quad (\lambda)^m d\lambda \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

This equation gives the solar flux coming to a surface anywhere on earth. Daily beam radiation energy can be computed by integration of Eq.11 within the limits of the local solar time, that is:

$$Q_{day} = \int_{t_1}^{t_2} Q_d(t).dt. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Yearly total beam radiation energy is the sum of the daily radiation energies for the whole year. In this paper, however, only the results of Eq. 12 is used since daily mean radiation values were required.

RESULTS AND DISCUSSION

Figure 1 shows all stations in which solar data are currently being monitored in Kenya. The results of solar insolation for the eleven Kenyan stations computed using the "Ege" model (12) is mapped out in Figure 2 together with the measured values as well as those obtained using the "Universal" formula (9). The percentage deviation of the two correlations from the measured values are shown in Table 1. The theoretical predictions from the "Ege" model are in good agreement with the measured values while the predictions from the "Universal" formula are in comparatively poor agreement with the measured values. It is to be noted that one basic difference between the two models and those given in the literature is that the model developed in this paper is that while our model uses known basic terrestrial data most commonly used correlations base their computation of solar radiation coming to a surface on extra-terrestrial radiation as follows:-

$$Q_t = Q_0(a+b(n/N)) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

where Q_0 - radiation outside of the atmosphere for the location, averaged over the time period in question.
a and b - constants depending on location.
n - average daily hours of bright sunshine for same period.
N - maximum daily hours of bright sunshine for same period.

Indeed, several authors have tried to obtain the values of "a" and "b" by the technique of least-squares. They have used measured values of Q_t, n and N and computed values of Q_0(1) to determine values of "a" and "b" from a first degree polynomial. Several such correlations are given in reference (15) where also the potential photosynthesis distribution of Kenya is discussed.

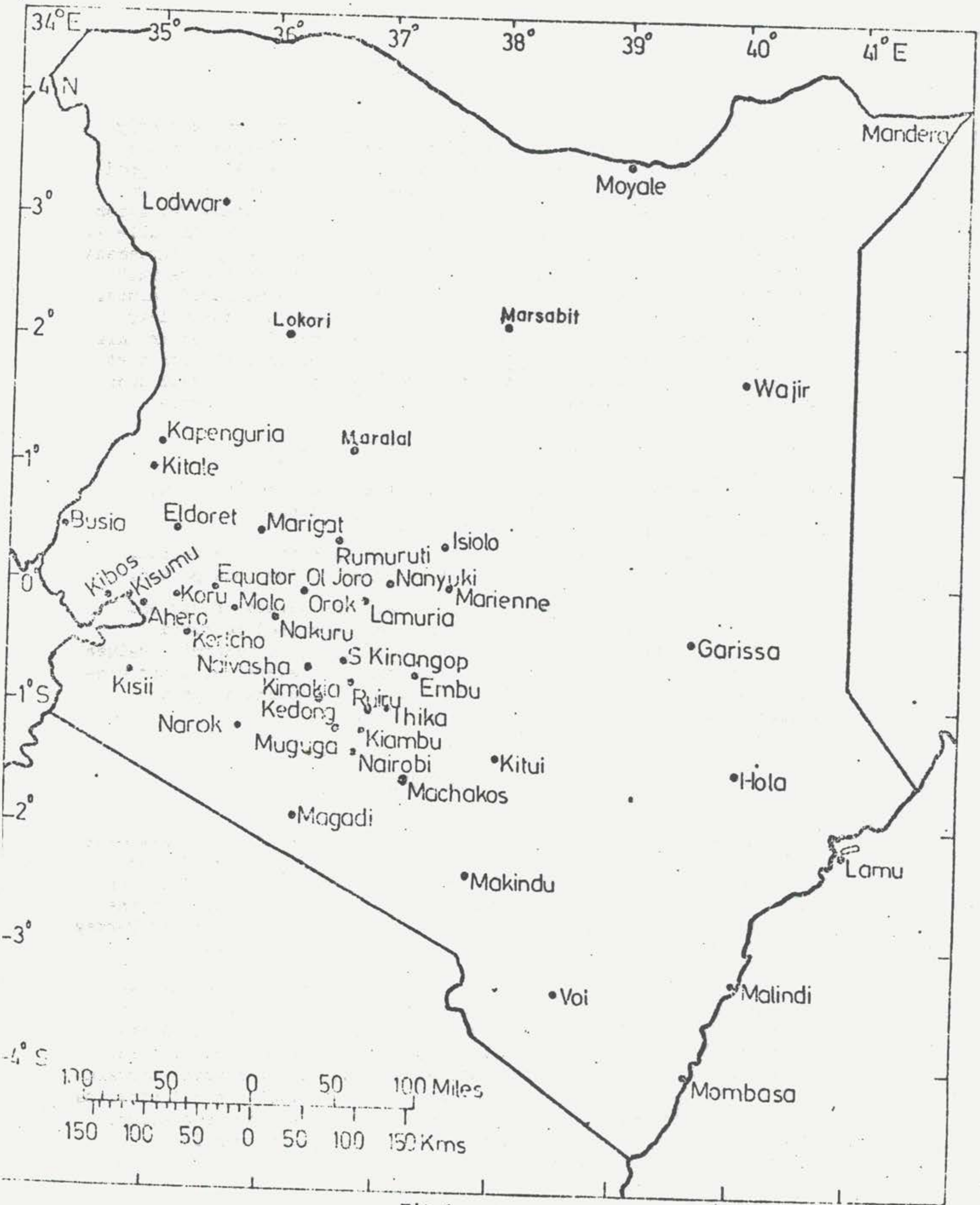
CONCLUSIONS AND SUGGESTIONS

The computed results using the "Ege" model are in good agreement with the measured data and therefore solar maps of Kenya and other East African countries could be constructed by this model. The maps would be dependable, cheap and easy to obtain. The results from the eleven stations are about a factor of ten above most stations in Turkey thereby showing that Kenya has a very good solar potential.

Kenya and her neighbouring countries could and should make as much use out of her potentials as possible, since the countries are just in the middle of what is known as "solar-belt" ($\mp 35^{\circ}$ of North and South of Equator). Continuous monitoring and recording of solar data would be very useful for comparing the results of several correlations. This suggestion does not imply a "countrywide" (in all province centres) measurements but at least three to five dependable stations and a mobile station are necessary for correcting the equations suggested in this and other models.

NOTE

The cost of running the program on an IBM 360/70 machine for the eleven stations of Kenya was 2342.89 Turkish Lira (1 U.S. Dollar=25 Turkish Lira). This would have been no more than about 50% higher if twice as many stations were to be considered. Once a study of this fashion is completed the data which would be obtained is the least expensive.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Maralal
Kitale
Busia
Eldoret
Marigat
Isiolo
Rumuruti
Kibos
Kisumu
Equator
Ol Joro
Nanyuki
Koru
Molo
Orok
Marienne
Ahero
Lamuria
Nakuru
Kericho
Garissa
Naivasha
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Kimakia
Embu
Ruiru
Kedong
Thika
Narok
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Fig.1

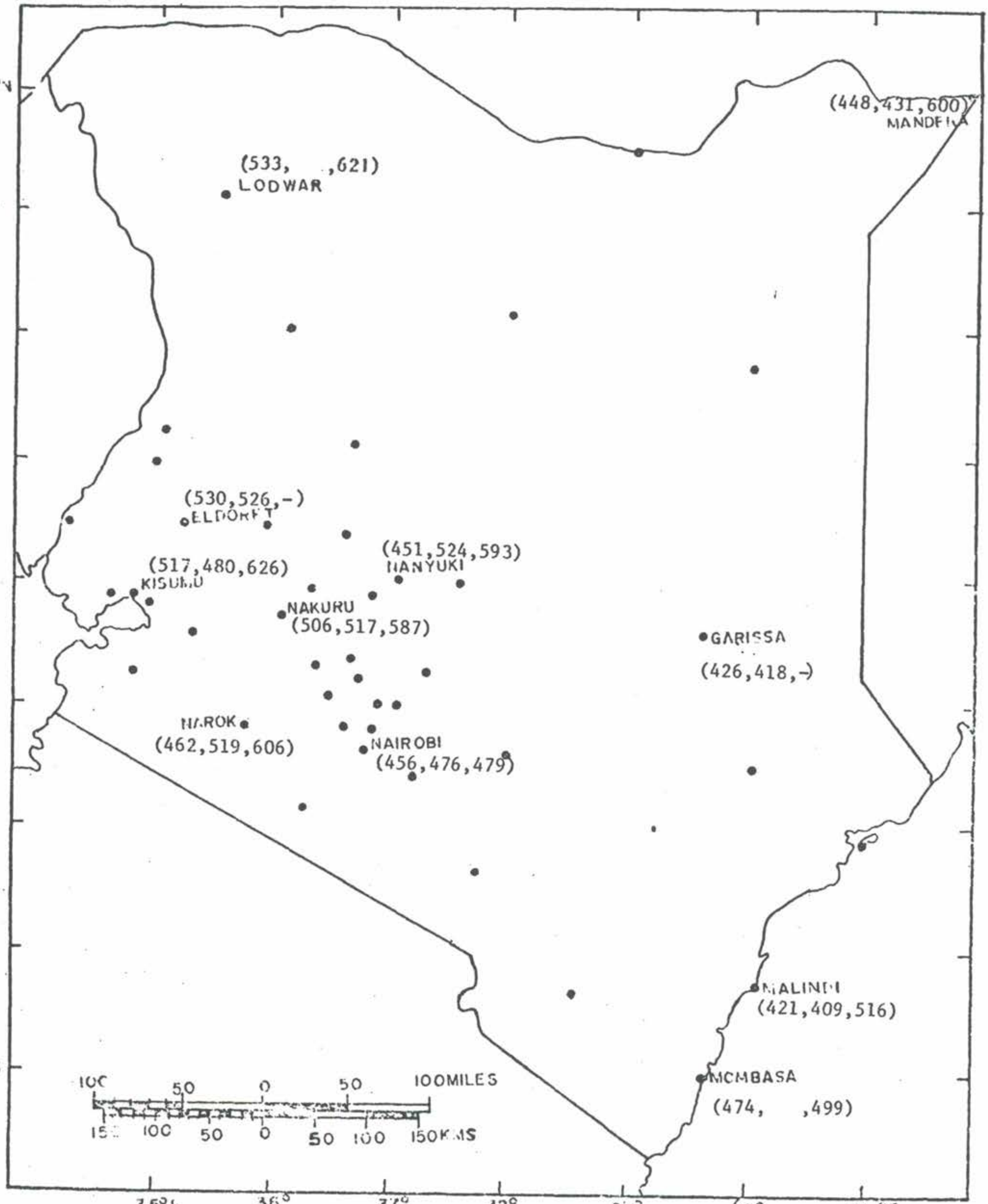

FIG.2 ANNUAL MEASURED, "EGE" AND "UNIVERSAL" SOLAR INSOLATION OF 11 KENYAN STATIONS

TABLE 1: PERCENTAGE DEVIATION OF THEORETICAL KENYAN SOLAR INSOLATION FROM MEASURED VALUES.

(E/M = "EGE" MODEL AND U/M = "UNIVERSAL" FORMULA MODEL)

KISUMU		MALINDI		MANDERA		NAKURU		NAROK		NANYUKI		NAIROBI		LODWAR		MOMBASA		ELDORET		GARISSA	
E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%	E/M%	U/M%
9	1	9	23	18	4	7	22	5	2	6	11	5	36		7		35	14		14	
8	6	2	11	10	5	2	11	9	8	20	3	4	22		1		28	12		9	
3	24	0	7	5	18	13	10	12	21	32	29	3	5		14		16	5		9	
3	33	1	24	1	38	13	32	17	44	33	55	14	28		29		18	3		12	
9	40	1	65	0	58	5	47	17	62	11	56	20	63		29		55	3		8	
12	43	5	79	2	74	3	54	13	66	4	65	21	86		36		68	2		8	
5	51	1	85	10	85	3	63	24	77	6	66	45	120		44		71	22		4	
4	41	1	63	6	67	5	47	21	60	8	51	47	95		33		48	9		1	
5	29	3	37	2	43	5	25	11	35	13	33	18	35		59		14	3		3	
6	4	6	8	4	37	8	9	8	20	30	31	13	8		12		9	4		6	
8	7	6	12	5	17	6	16	13	15	41	27	14	5		1		28	1		11	
16	14	7	24	20	7	9	26	1	11	2	18	2	27		16		38	10		12	

REFERENCES

Duffie, J.A. and Beckman, W.A., "Solar Energy Thermal Processes", John Wiley and Sons, Inc. (1974).

DeJong, B., "Net Radiation Received by a Horizontal Surface at the Earth", Delft University Monograph, Netherlands, (1973).

Löf, G.O.G., Duffie, J.A. and Smith, C.O., "World Distribution of Solar Radiation", Solar Energy, 10, 27(1966).

Liu, B.Y.H. and Jordan, R.C., "The Interrelationship and Characteristic Distribution of Direct, Diffuse and Total Solar Radiation", Solar Energy, 4, No.3 (1960).

Norris, D.J., "Correlation of Solar Energy with Clouds", Solar Energy, 12, 107 (1968).

Thekaekera, M.P., "The Solar Constant and Spectral Distribution of Solar Radiant Flux", Solar Energy, 9, 7 (1965).

Heywood, H., "The Computation of Solar Radiation Intensities", Solar Energy, 10, 51 (1966).

Sayigh, A.A.M., "A Universal Formula for Predicting Solar Insolation", private communication, (1977).

Sayigh, A.A.M., "Estimation of Total Radiation Intensity, A Universal Formula", Fourth Course on Solar Energy Conversion, Trieste, Miramare (1977).

Mukolwe, E., "Regression Analysis of the Mean Monthly Sunshine and Radiation in East Africa", University of Nairobi, Department of Meteorology (1977).

Robinson, N., "Solar Radiation", Elsevier Publishing Co., New York (1966).

Karagülle, "Theoretical and Experimental Investigation of a Model of a Solar House", PhD Thesis, Ege University, Faculty of Engineering, Izmir, Turkey (1977).

Beba A. and Karagülle, N., "A Study of Solar Radiation Energy Distribution of Turkey", Izmir International Symposium-I on Solar Energy Fundamentals and Applications, Izmir, Turkey (1977).

Herry, J. and Smith, R.C., "Letters", Sky and Telescope, October, 1971, pg. 204.

Obasi, G.O.P. and Rao, N.N.P., "A Detailed Study of Solar Radiation and Potential Photosynthesis Distribution in Kenya", World Meteorological Organization. Proceedings of the UNESCO/WMO Symposium on Solar Energy, Geneva (1976).

A COMPARISON OF METAL AND CLAY CHARCOAL COOKING STOVES

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SUMMARY

The traditional African metal charcoal cooking stove is compared to a burnt clay stove which is common in Asia. Both stoves are described as experiments undertaken to determine their efficiency and the results of these experiments tabulated. It was found that at least 40% of charcoal could be saved by the individual householder if the clay stove was substituted for the metal stove. There would also be a considerable saving of cooking time, perhaps a third or more if the switch was made. The implications of introducing a clay stove in Africa are: an overall saving of energy, time and money; a saving of foreign exchange; a reduction of the area of woodland, forest or plantation required to meet the household requirements for charcoal. It is concluded that such savings should be welcomed by individuals and governments.

INTRODUCTION

The use of charcoal for household cooking is common in urban areas of East Africa. In 1970, over 40% of urban households in Tanzania used charcoal for cooking (Openshaw, 1971) and the number of users appears to have increased since then. In the Machakos district of Kenya all urban household used charcoal in 1978 (Mung'ala, 1978). Even in rural areas charcoal is used to a certain extent. 5% of the rural population in Tanzania (Openshaw, 1971) and 65% of rural Machakos (Mung'ala, 1978) used charcoal. The estimated total household consumption of charcoal for the above two areas is shown in Table 1. It amounted to 104,400 tonnes for Tanzania and 26,600 tonnes for Machakos district.

Table 1. Household consumption of charcoal in tonnes

	Tanzania (1970)		Machakos (1978)	
	Population 1,000	tonnes	Population 1,000	tonnes
Urban	760	64,100	27	3,900
Rural	11,540	40,300	876	22,700
Total	12,300	104,400	903	26,600

Sources: Openshaw 1971, Mung'ala 1978

The cost of charcoal from the shop or trader is about shs. 880.-* per tonne (1978 prices), therefore the householder paid approximately 92 million shillings for charcoal in Tanzania and 23 million shillings in Machakos. If more efficient cooking stoves could be introduced then a considerable saving for the householder may be made.

Types of cooking stoves

The traditional charcoal cooking stove in Africa is made of metal. Figure 1 a. This is a robust stove but it radiates much heat outwards as well as upwards. In South East Asia the traditional cooking stove is made from clay, Figure 2, and while not as robust as the African one, the stove appears to be more efficient because of the insulation properties of clay. In order to test this hypothesis a series of experiments were carried out to compare the two types of stoves.

MATERIALS AND METHODS

Stove description

Before presenting the results of the experiments, a description of the two stoves will be given.

The metal stove is made mainly from scrap metal of about 1 mm thick but some new steel rods are used for the three pan supports, however it can be said that originally most of the material had to be paid for in foreign exchange. The metal stove comes in various sizes but the measurements shown in the diagram (Figure 1) are for a typical household one. The fire grate is made of metal and usually has about 10% or less air space. The air inlet has a door so that the flame may be damped down.

The clay stove describes here originated in Thailand. It usually has three layers, although the stoves may be purchased without the outer metal cover and middle ash layer. It is almost entirely made from local materials - clay and ash - with only the outer metal being paid for in foreign exchange. This outer metal cover is to give the stoves more durability. It is generally made from old tin cans such as are used for packing beer and fruit. The middle layer is filled with ash (rice straw ash in this particular case) ahd has a simple cement seal to contain the ash. The inner layer is made of burnt clay of about 3 cms thick at the top tapering to about 1 cm at the base. The fire grate is made of the same burnt clay material and secured with cement. If the grate breaks it can be replaced without the need to buy a new stove. It is usual to buy one or two extra grates at the time of purchasing the stove. The air space in the grate is about 25 % of the basal area, this compares with about 10 % in the metal stove and could be one of the design features which makes this type of stove more efficient. The clay stove has a larger diameter at the top than the base and this acts as a kind of self stoking device. It was noticed that unlike the metal stove the charcoal never had to be moved around to obtain a complete burn, another good design feature. The rim of the stove has three raised platforms which support the pots and pans and three depressions which allow an inflow of air at the top which supplements the air inflow at the base.

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* 7.5 E.A. shillings approximately equal US $ 1.

Fig. 1a

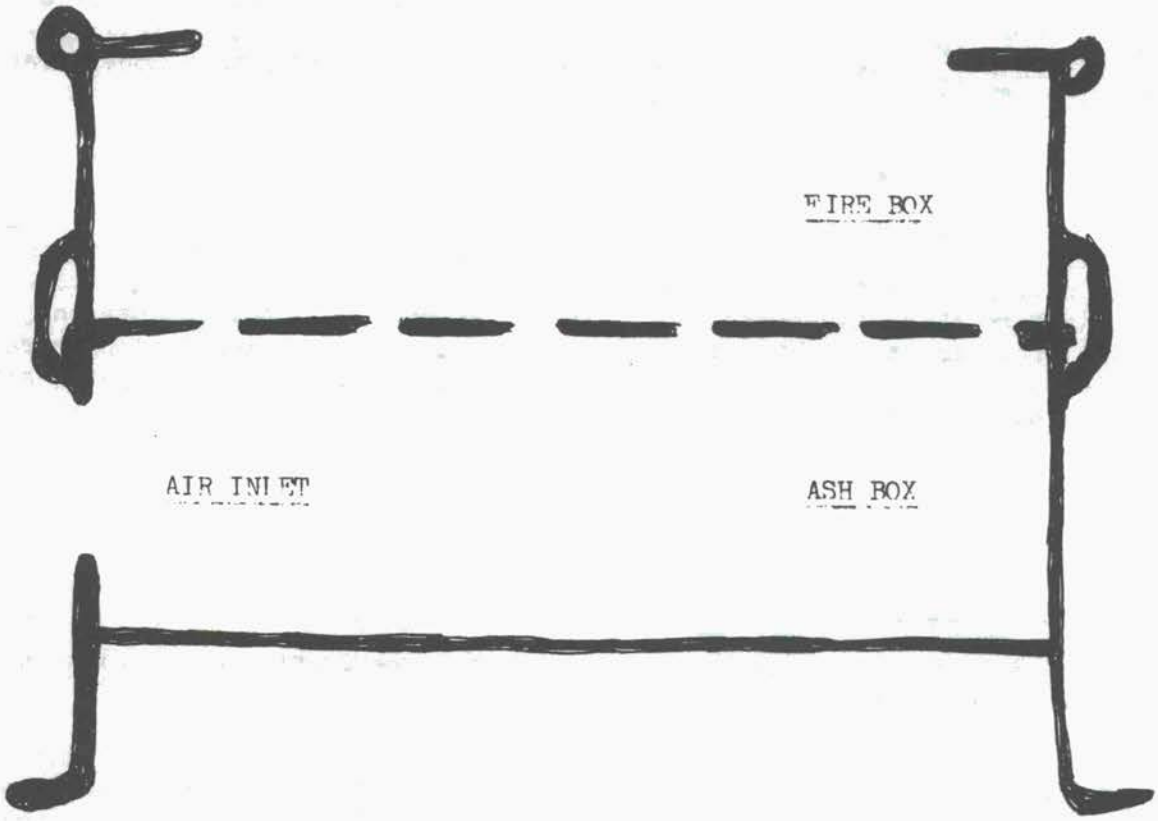


Fig. 1b

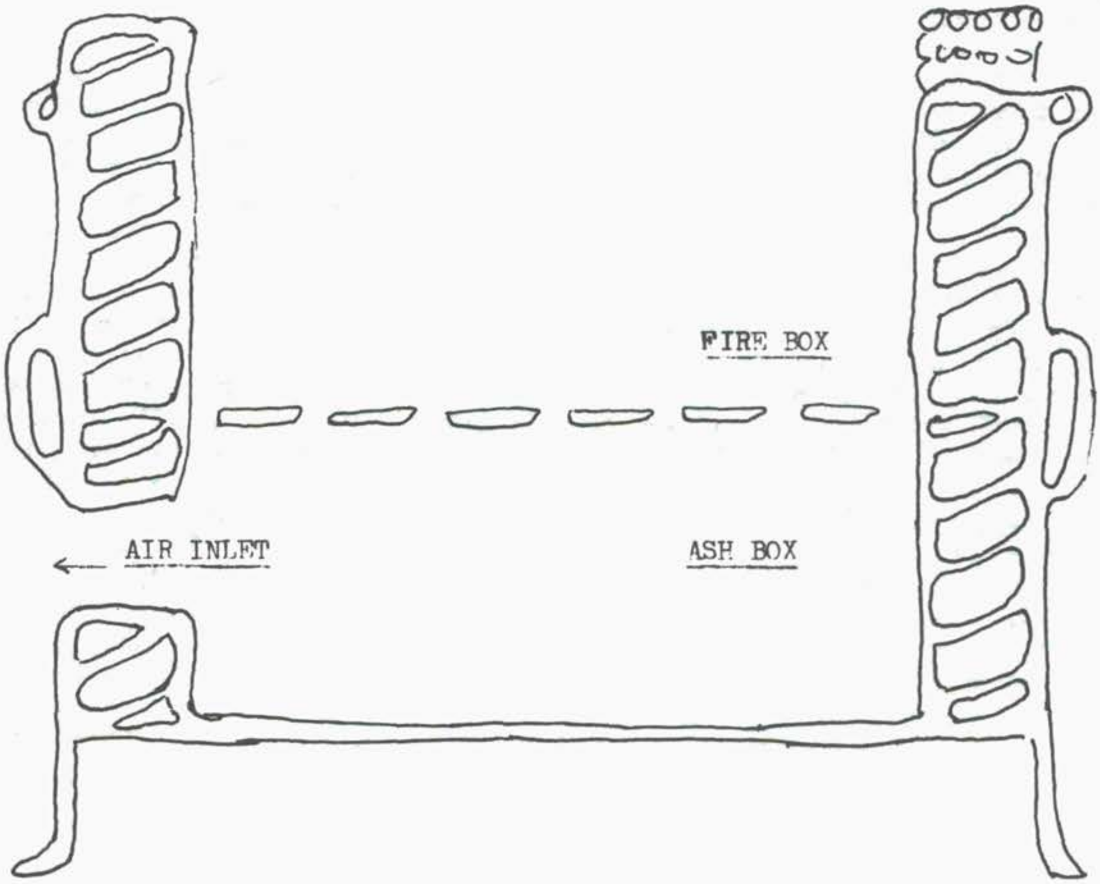
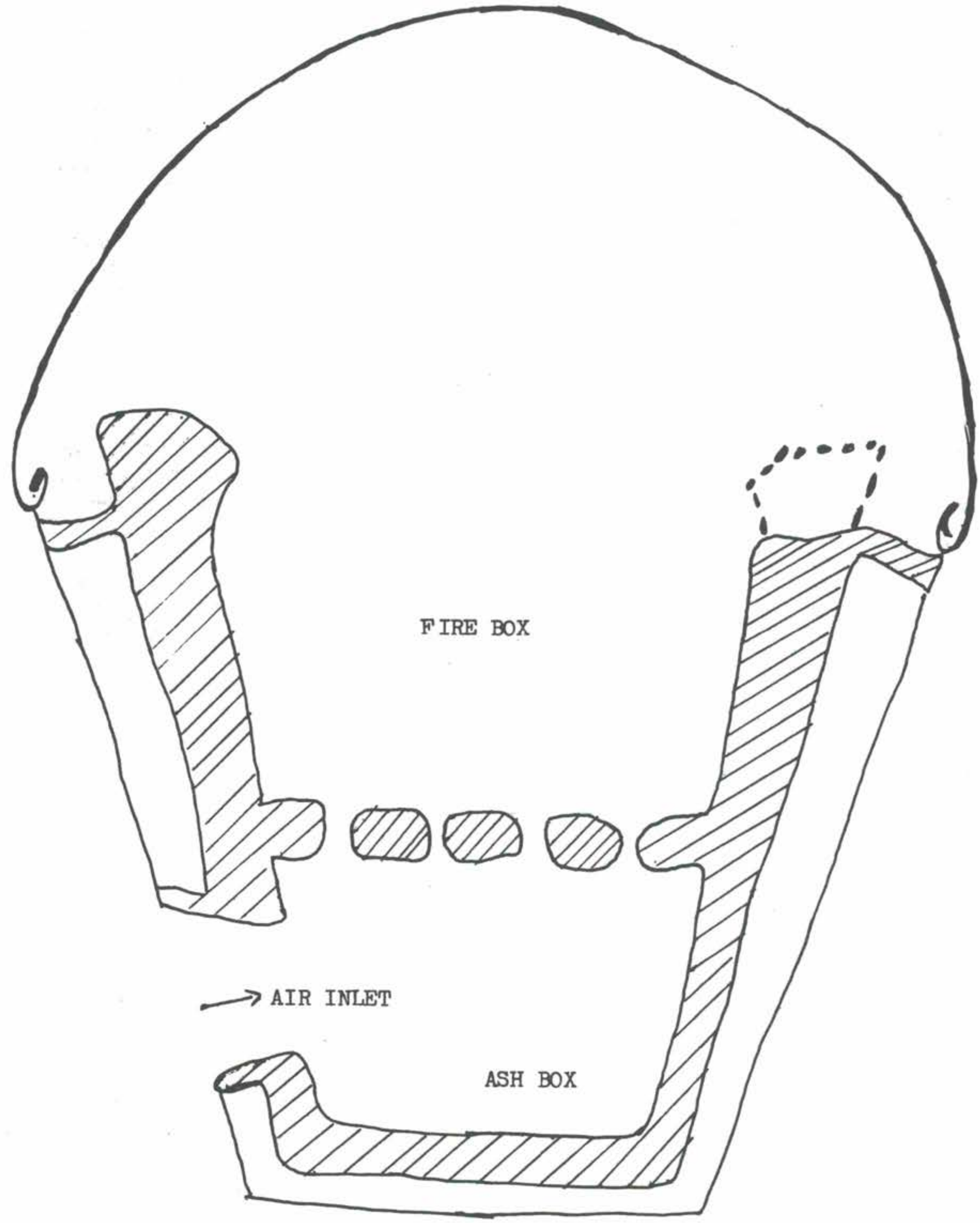


Fig. 2



The basal air intake does not have a door but it may be restricted by using a brick. Again there are various sizes of the stove but the dimensions shown in Figure 2 are typical for household use.

The fire box volume of the two stoves is approximately the same but as can be observed the dimensions are completely different. Although the metal stove has a larger diameter, the clay stove can still accomodate the same pan sizes as the metal stove, namely 27 cms (large), 23 cms (medium) and 17 cms (small) diameter without loss in efficiency and the design enables spherical bottomed frying pans to fit snugly into the well of the fire box, making deep hot frying practical.

A modified metal stove was also used in the experiment. The modifications consisted of : lining the inside of the fire and ash boxes with local clay about 3 cms thick, incorporating into the design three raised platforms of clay as pan supports, and increasing the airspaces in the metal grate to approximately 25 % of the area (figure 1b).

<u>Method of manufacture of the clay charcoal stove</u>

In Thailand the method of manufacture is briefly as follows : two parts of (delta) clay are mixed with one part of (rice straw) ash, plus water and the plastic mixture is then shaped in a mould. The moulded clay stove is then burnt in an open brick kiln for approximately 48 hours using rice straw as the heat source. The fire grate is made in a similar fashion except a 1 to 1 mixture is used, and then cemented into the stove. The outer metal container is made from old tin ca s and the burnt clay kiln is placed inside the container and the space between filled with (rice straw) ash and sealed with cement. The method and mixtures differ slightly from place to place and if production started in East Africa the manufacturer would first have to experiment to obtain the correct mixture and firing time. Also a substitute for rice straw (maize stalks?) would have to be found. These problems are to be examined by a student in the Division of Forestry here at Morogoro. He will be looking into the whole question of design, manufacture and adoption of the clay stove.

<u>Experiments to compare the two types of stoves</u>

Two sets of experiments were undertaken to compare the efficiency of the two stoves, the measures of efficiency being taken as time taken to boil water, and the amount of water boiled or evaporated. The charcoal used was mixed miombo (open) woodland species bought from the road side. It had an average moisture content of between 15 and 20 %.

In the first set of experiments 500 grammes of charcoal were burnt using newspaper to light the coal and the amount of water evaporated was measured. The ash content of the two stoves was weighted as was any unburnt charcoal that remained. The temperature at 6 cms from the stove and 8½ cms from the ground was also measured, as was the inside stove temperature after the charcoal had burnt out.

The second set of experiments was in the form of a field trial. The clay stove was simultaneously compared with one or two metal stoves or the modified metal/clay stove. 400 gramme bags of charcoal, again of mixed miombo species, were distributed randomly to the stoves. The trial took place on seven consecutive days and eight burns were made in the clay stove, fourteen in the metal stoves and three in the metal/clay (modified) stove. Each stove was lit using one sheet of newspaper and 50 cc paraffin. Water was brought to the boil, one litre at a time in standard sized aluminium pans with lids (23 cms diameter and 10 cms deep) and the total number of litres brought to the boil was recorded, as well as the total and per litre time. The boiling temperature was taken as 96 C for the experiment took place at Morogoro which is more than 500 metres above sea level. As soon as one litre had boiled another standard pan containing cold water was substituted. The temperature of the water before boiling was about 22 C. The weather conditions varied somewhat from day to day. Some days being overcast others sunny, some days there was a breeze others it was still, and the people undertaking the experiment varied. The experiment took place at 9.30 a.m. and once at 2.30 p.m. Stop watches were used to record the time and thermometers the temperature.

RESULTS AND DISCUSSION

Experiment 1

The results from experiment 1 may be summarized as follows :

(i) Ash content and unburnt charcoal

500 grammes of charcoal were burnt in each of the two stoves, the charcoal was from the same source at any one burn. A total of four burns were undertaken giving the following results (Table 2).

Table 2. Ash and unburnt charcoal content

	Stove type		Stove type	
	Clay	Metal	Clay	Metal
	Average % of original wt. (500 g)		Average % of burnt charcoal	
Ash content	6.3	9.3	6.3	9.7
Unburnt charcoal	0.1	3.9	-	-
	% range of original wt.		% range of burnt charcoal	
Ash content	6.6 - 5.9	12.0 - 5.3	6.6 - 5.9	12.6 - 5.7
Unburnt charcoal	0.4 - 0.0	6.9 - 1.6	-	-

The above results present somewhat of a paradox, while the ash content is greater by about 50% in the metal stove, it was produced from a smaller amount of charcoal for there was about 4% charcoal left after burning whereas for the clay stove a negligible amount remained.

(ii) Temperature

It could be observed that during the burn the charcoal in the clay stove became white hot, whereas the colour of the burning charcoal in the metal stove was much redder. The inside temperatures of the clay stove after all the charcoal had burnt was greater than 110 C but the temperature in the metal stove was 106 C. The temperature during burning 6 cms from the clay stove and 8½ cms above ground level was 33 C whereas that recorded for the metal stove at the same distance and height was 41 C showing that much more heat was being radiated from the latter.

(iii) Water evaporated and time to evaporate the water

Thirty percent less water was evaporated with the metal stove and it took 50 % more time to evaporate this smaller volume. Therefore it would reauire 43 % more charcoal to evaporate the same volume of water and it would take twice as long.

Experiment 2

The results of the trial may be summarized as in Table 3 and Table 4. Table 3 gives the amount of water boiled whereas Table 4 gives the time to boil the water.

On average twice as much water was boiled in the clay stove as compared with the metal stove and therefore only half the quantity of charcoal was required to boil one litre using a clay stove compared to a metal stove. Even allowing for the unburnt charcoal and assumung it could be used again giving out the same calorific value as "fresh" charcoal, then an average 48 % more charcoal is required with a metal stove to boil the same volume of water. The modified metal stove on the other hand only required 10 % more charcoal to boil the same volume of water, however as will be seen in Table 4 it took a much longer time. Also the metal and clay stove was the most difficult to light and to get going really well. The clay stove lit the easiest, it could be started just with twigs and paper, and within five to ten minutes it was burning brightly. A statistical analysis (t test) was undertaken for the clay and metal stove results and the difference between the two amounts boiled was significant at the 0.01 level (appendix 2). The results of the experiment are recorded in Appendix 1.

It will be seen from Table 4 that the average time for boiling water on the clay charcoal stove is approximately two thirds of the time taken to boil water on the metal stove and even less (60 %) when compared to the modified metal stove.

If a comparison is made over the same number of litres boiled, in this particular case 4 litres, then the average time for boiling water on the clay stove is less than 60 % of the time spent on the metal stove and there is very little difference between the times of the metal and modified metal stove. It can be seen therefore that there is not only a considerable saving of energy but also a significant saving of time. Of course this saving of time is only useful for certain cooking operations - boiling water and frying for example. When food has to be simmered for long periods of time then it could be argued that there will be an increased consumption of charcoal with the clay stove. However, in Thailand this snag is overcome by damping down the stove by partially or completely blocking off the lower air intake and only placing small quantities of charcoal on the stove at any one time. The Thais also prefer to buy a denser (and more expensive) charcoal made from mangrove species which burns more slowly compared to other local charcoal species. The modified metal stove proved to be more efficient than the original metal stove but no saving was made in time. As a first step however it may be advisable for the "African" householder to line the metal stove with clay and also to increase the air space in the fire grate. A "t test" was carried out to see if there was any significant difference between the quickest average time to boil 1 litre on the clay stove (the 3rd litre average time 6.71 minutes) and in the metal stove (the 2nd litre average time 11.28 minutes). The statistical analysis showed the difference between the two was significant at 0.05 level (appendix 2). Because only three trials were undertaken with the metal/clay stove no statistical comparison could be made with the other two stoves.

Table 3. Comparison of charcoal stoves - amount of water boiled

Stove type	Clay	Metal and Clay	Metal
No. of stoves	1	1	2
No. of trials	8	3	14
Wt. of charcoal used per trial (grammes)	400	400	400
Total no. of litres boiled	50	17	44
Average no. of litres boiled per trial	6.25+	5.67	3.14+
Average weight of charcoal used per litre boiled (grammes)	64	71	127
Average K. calories used to bring each litre to the boil (assume 7.9K. cals per gramme)	506	561	1,003
Cost of boiling a litre of water in cents assuming a cost of shs. 1.- per kg.	6.4	7.1	12.7
Percentage of charcoal remaining after burning (see Table 2)	0	2*	4
Adjusted weight of charcoal used per litre boiled (allowing for burnt charcoal) grammes	64	69	122
K. cals. used per litre boiled	506	545	964
Cost to boil 1 litre in cents	6.4	6.9	12.2

* assumed.

\+ significant difference between the two averages at the 0.01 level.

Table 4. Comparison of charcoal stoves – time to boil water

Stove type	Clay		Metal and Clay		Metal	
No. of trials	8		3		14	
Weight of charcoal used per trial (grammes)	400		400		400	
Average time to boil water in minutes	Av.	Culm.	Av.	Culm.	Av.	Culm.
1st litre	9¼		20		13¼	
2nd litre	7¼	16½	10 3/4	30 3/4	11¼+	24½
3rd litre	6 3/4+	23¼	11 3/4	42½	14½	39
4th litre	8	31¼	13	55½	16¼	55¼
5th litre	8 3/4	40	14	69½	(16 3/4	72)
6th litre	9	49	(22¼	91 3/4)	-	-
7th litre	10	59	-	-	-	-
8th litre	(15 3/4	74 3/4)	-	-	-	-
Average time taken to boil 1 litre of water (minutes)	9.30		14.90		13.70	
Average time to boil 1 litre for the first 4 litres	7.80		13.00		13.60	

Av. – average; Culm. – culmulative.

+ Significant difference between the two times at the 0.05 level.

<u>Note</u>: The figures in brackets represent only the average of one or two results.

Implication of the introduction of clay stoves

Economic saving

All in all it can be seen that the clay stove has a marked advantage over the metal stove not only in saving of charcoal and time but in its versitility. Its one draw back is that it is not as robust as the metal stove but with careful handling the average life is between two and three years.

What are the implications for East Africa if clay stoves could be introduced ? First of all there would be an overall saving of energy, but not necessarily charcoal, for if the housewife only requires about half the quantity of charcoal to cook the same meal the relative price compared to other forms of energy will decrease and people may switch from fuel-wood, paraffin and gas to charcoal. If this occurs then consumption of charcoal may actually increase but at the expense of the other fuels and therefore the overall effect should lead to a decreased consumption of energy and saving of foreign exchange.

Incidentally if metal charcoal kilns could replace the traditional earth kilns in the production process the amount of charcoal produced from the same input of wood raw material would double (Openshaw 1978), so again this should lead to an overall energy saving and the combination of these two energy saving measures could lead to a reduced demand for roundwood for charcoal manufacture.

Table 1 gave the household consumption of charcoal for Tanzania and Machakos district of Kenya. This physical measure can be translated in money terms and this is shown in Table 5. This table also shows the approximate amount of money that could be saved per year if clay stoves were to completely replace metal stoves and assuming that at least 40% of the charcoal volume could be saved.

Table 5. Annual amount of money spent by householders on charcoal with an estimate of the amount that could be saved

Year	Urban	Rural	Average	Urban	Rural	Total
	Value in shs. per household spent on charcoal (users only)			Total value in million shillings		
Tanzania 1970	332	296	317	56.4	35.5	91.9
Machakos 1978	618	412	433	3.4	20.0	23.4
	Possible household saving in shs. per year (users only)			Total possible savings in million of shillings		
Tanzania 1970	133	118	127	23	14	37
Machakos 1978	247	165	173	1	8	9

Note: It has been assumed that charcoal costs shs. 880.- per tonne to the householder. (This figure is more or less correct for Kenya and Dar-es-Salaam, but they may be an overestimate for Tanzania excluding Dar-es-Salaam. The average price in 1978 outside Dar-es-Salaam was between shs. 550-600 per tonne).

It will be seen that for the individual users of charcoal, it is possible to save up to the equivalent of two weeks wages, and for total Tanzania or Machakos the "saving" would run into many millions of shillings. If in fact people did switch to charcoal from gas and paraffin then the saving of foreign exchange would be greater for the cost per K. cal. for imported fuels is more expensive than the K. cal. cost of charcoal. The projected "saving" would have to be offset against an additional cost of purchasing the less durable clay stove. The cost of the clay stove under trial was the equivalent of shs. 7.- in Thailand, this is less than the cost of a metal stove. Even if the stoves sold for shs. 10.- each, upto 13 stoves could be purchased each year before the savings made on charcoal consumption offset the loss made on stove purchase. As indicated previously with careful handling the stoves should last two or three years and thus the overall saving to the householder should be positive and substantial.

Supply of charcoal

The introduction of a more efficient charcoal stove must go hand in hand with the introduction of more efficient fuelwood stoves as well as better methods of charcoal production. However, it is of little use introducing all these "superior" pieces of equipment if the wood source is not guaranteed. Each region and district requires an adequate supply of wood raw material in order that the energy needs of the population can be met from local sources. Village woodlots and plantations to serve urban areas will have to be started if the natural forests and woodlands in particular areas are inadequate.

Table 6 gives an idea of the wood raw material requirements of a household of five people using charcoal either produced by the traditional earth kiln or by a metal kiln and cooking on a metal or clay charcoal stove.

Table 6. Volume of wood raw material used per household of 5 people per year assuming alternative production and consumption

Manufacturing process	Stove type Metal	Clay
	Units: m^3 per year of roundwood equivalent	
Earth kiln	8.50	5.10
Steel kiln	4.25	2.55

Note: It has been assumed that on average each urban household uses 0.71 tonnes of charcoal per year for cooking (Machakos 1978 figures). Some of the charcoal is used for ironing and not cooking but this could be offset by the non-household use of charcoal for cooking which has not been considered in this article.

It will be seen that if steel kilns and clay cooking stoves could be introduced then more than three times as many householders could be satisfied from the same roundwood volume. A fuelwood plantation should yield on average between 10 m^3/ha/year and 25 m^3/ha/year depending on species used and rainfall, the former yield being in relatively dry areas and the latter inrelatively wet areas. Table 7 gives an indication of the area needed per household (5 people) to meet the annual requirements of charcoal.

Table 7. Area of plantation required in hectares to meet annual household demands

Manufacturing process	Area in hectares			
	Stove type		Stove type	
	Metal	Clay	Metal	Clay
	"Dry area" Average growth 10 m^3/ha/year		"Wet area" Average growth 25 m^3/ha/year	
Earth kiln	0.85	0.51	0.34	0.20
Steel kiln	0.42	0.26	0.17	0.10

It can be seen from Table 7 that when planning future charcoal plantation schemes it is most important to know the production and consumption methods.

From earlier calculations it should be practical to grow wood for charcoal production selling at about shs. 20.- per m^3 and give a return on investment of about 10% (Openshaw 1978). Given this stumpage price the charcoal manufacturer should be able to obtain at least a 10% return on investment. What is more the energy will be supplied from within the country and employment opportunities will be created especially in the rural area.

DISCUSSION AND CONCLUSIONS

The present method of cooking on a metal charcoal stove is inefficient when compared to a clay stove, this is mainly because of the superior thermal insulation properties of clay, however design could have an effect as well. If a clay stove could be introduced into East Africa, there could be a household saving of up to half the money spent each year on charcoal purchase, but this does not necessarily mean that the country will save on charcoal for there may be a switch from other forms of fuel, nevertheless there will be an overall saving of energy and most likely, a saving of foreign exchange. The introduction of the clay stove may be a problem but it would pay the government to employ demonstrators and give out free stoves initially. If the stove is accepted then it could lead to increased charcoal consumption and stimulate government and local authorities to start plantations and village woodlots. After all any devices that could save individuals up to half their energy requirements for cooking and up to one third of the time spent on cooking should be welcomed with relief by the country and enthusiasm by the housewife.

REFERENCES

Mung'ala, P.M., 1978. Estimation of present consumption and future demand for wood fuel in Machakos district of Kenya. M.Sc. (For) Thesis. Division of Forestry, University of Dar-es-Salaam, Morogoro.

Openshaw, K., 1971. Present consumption and future requirements of wood in Tanzania. FAO, Rome. SF/TAN 15, Technical Report 3.

Openshaw, K., 1978. Woodfuel: A time for reassessment. Natural Resources Forum, Vol. 3 no. 1, October 1978. United Nations, New York.

APPENDIX 1 **Results of the field trial to compare different charcoal stoves**

Clay Stove - Time in minutes to bring 1 litre of water to 96 C (from 22 C approx.)

No. of litres boiled	Experiment								Average
	1	2	3	4	5	6	7	8	
1	9.9	11.85	11.8	9.0	7.0	7.7	8.5	8.0	9.22
2	9.0	7.9	12.5	6.35	5.95	5.7	5.2	5.35	7.24
3	6.0	8.65	13.05	5.65	5.0	4.9	5.9	4.55	6.71
4	8.4	11.0	15.6	6.3	5.45	6.4	5.45	5.7	8.04
5	16.6			9.5	6.5	6.1	6.05	7.3	8.68
6				10.8	6.95	8.0	6.95	12.1	8.96
7					8.0	10.0	8.05	14.1	10.64
8					14.45	17.4	15.3		15.72
Total litres boiled per experiment	5	4	4	6	8	8	8	7	6.25

APPENDIX 1 (Continued)

Metal Stove - Time in minutes to bring 1 litre of water to 96 C (from 22 C approx.)

No. of litres boiled	Experiment							
	1	2a	2b	3a	3b	4a	4b	5
1	21.45	17.75	11.8	12.1	17.2	21.6	11.2	11.0
2		24.35	10.2	14.25	11.3		15.7	6.5
3			17.25	25.65	17.2		19.55	6.2
4			25.65					10.3
5								13.2
Total litres boiled per experiment	1	2	4	3	3	1	3	5

No. of litres boiled	Experiment						Average
	6a	6b	7a	7b	8a	8b	
1	15.9	8.1	10.5	7.65	9.6	10.25	13.29
2	11.1	8.2	6.1	7.75	9.9	9.95	11.28
3		18.7	7.5	10.3	13.85	8.3	14.45
4			15.4	15.75	19.15	10.8	16.18
5			20.5				16.85
Total litres boiled per experiment	2	3	5	4	4	4	3.14

APPENDIX 1 (Continued)

Metal/Clay Stove - Time in minutes to bring 1 litre of water to 96 C (from 22 C approx.)

No. of litres boiled	Experiment			Average
	5	6	7	
1	22.5	13.5	23.8	19.98
2	13.45	8.7	10.2	10.78
3	14.35	11.2	10.1	11.88
4	15.6	12.8	10.4	12.93
5	17.35	15.15	12.8	13.93
6		22.3	22.25	22.28
Total litres boiled per experiment	5	6	6	5.67

Note:

1. The experiments took place on seven consecutive days at the same time in the morning (9.30 a.m.) except experiment 8 which took place at 2.30 p.m. on the last day.

2. The experiment no. refers to the day except experiment 8 which took place on day 7.

3. For the metal stoves, up to two stoves may have been compared with the clay stove and these stoves have been numbered a and b. Hence on day 2 two metal stoves (2a and 2b) were compared with the charcoal stove.

APPENDIX 2 Statistical analysis (t test)

(a) Comparison of the average numbers of litres boiled on a clay stove and metal stove

Hypotheses. There is no statistical significant difference between the average number of litres boiled on the clay stove (6.25) and the average number boiled on the metal stove (3.14).

	Clay stove	Metal stove
No. of experiments	8	14
Mean (no. of litres boiled)	6.25	3.14
Sum of deviation from mean	0	0
Sum of squares of deviation from mean	21.5	21.71
Degrees of freedom (d.f.)	7	13

Estimate of variance (S^2) = $\frac{21.50 + 21.71}{7 + 13} = 2.16$

Estimated variance of the difference = $\frac{2.16}{8} + \frac{2.16}{14} = 0.42 = (0.65)^2$

Estimated standard error of the difference = 0.65 litres boiled

Observed difference = 6.25 - 3.14 = 3.11 litres boiled

Ratio of the difference (t) = $\frac{3.11}{0.65} = 4.78$

Significant level for 0.01 probability with 20 degrees of freedom 1 = 2.85

4.78 is much larger than 2.85 and therefore the hypotheses can be rejected. There is a very significant difference between the two stoves.

Note: A statistical comparison (t test) cannot be made between the metal/clay stove and the other stoves as insufficient data for the metal/clay stove has been collected to make the comparison meaningful.

APPENDIX 2 (Continued)

(b) Comparison of the average time to boil one litre of water on the clay stove and the metal stove

Hypotheses. There is no statistical significant difference between the average time to boil 1 litre on the clay stove (6.71 minutes) and the average time to boil 1 litre on the metal stove (11.28 minutes). In this case a comparison is being made between the quickest average time it took to boil one litre; for the clay stove this was the third litre and for the metal stove it was the second litre.

	Clay stove	Metal stove
No. of experiments	8	12
mean (minutes per litre)	6.71	11.28
Sum of deviation from mean	0	0
Sum of squares of deviation from the mean	56.86	275.86
Degrees of freedom (d.f.)	7	11

Estimated variance $(S^2) = \dfrac{56.86 + 275.86}{7 + 11} = 18.48$

Estimated variance of the difference $= \dfrac{18.48}{8} + \dfrac{18.48}{12} = 3.85 = (1.96)^2$

Estimated standard error of the difference = 1.96 minutes

Observed difference = 11.28 - 6.71 = 4.57 minutes

Ratio of difference $= \dfrac{4.57}{1.96} = 2.33$

Significant level for 0.05 probability with 18 d.f. = 2.11

2.33 is larger than 2.11 and therefore the null hypotheses can be rejected. There is a significant difference in boiling times between the two stoves.

A FEASIBILITY OF EXPLOITING RENEWABLE SOURCES OF ENERGY IN RURAL AREAS

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At present about 80% of the African people are living in rural areas - if we exclude the North African Countries, a large amount of energy consumed in these countries (perhaps more than 60%) is produced by the use of fuel-wood, charcoal, and residues. 1/

If we consider only rural householder's energy consumption and not the big energy consumers, such as rural food processing factories, this proportion is almost 100% since, at present, most of the African rural areas are very poorly equipped with energy consuming commodities such as lighting, water pumping, grinding, water heating, public transportation, etc.

One way to improve the present living conditions in rural areas is to make more energy available for rural population in a useful form to satisfy real needs. The most important source of energy in evidently fuelwood to which many papers of this seminar are devoted. On the other hand, beside fuelwood, how to know what are the useful forms of energy? What are the real needs to be satisfied and whichare the priorities? To answer these questions precisely, surveys, such as the survey presently undertaken in Kenya, are needed. Many tests are also needed in hundreds of villages in Africa as recommended by Mr. HOWE in order to ascertain to what extent such technology is appropriate in the African context. 2/

I fully agree with the need for such surveys and tests but I do not agree that we must wait for the results of these surveys and tests in order to undertake concrete actions if limited to well-proved technologies and to well known needs such as lightings, water pumping and grinding. Kerosene lamps and small diesel generators are well established technologies but it will be desirable at least in non-oil producing countries such as Kenya, to find alternatives in the fields of renewable sources of energy.

Renewable sources of energy have the advantages of being locally available and therefore expensive transportation systems are not needed. Also they can be harnessed by equipment which usually needs little maintenance and which is well adapted to rural energy demands since their power output ranges from a few watts to some kilowatts.

On the other hand, renewable sources of energy have several disadvantages such as :

1) It is generally more expensive to set up a non-conventional energy plant as opposed to conventional ones

2) Very often qualified experts able to make the preliminary studies of a solar, wind or bio energy project are just not available in developing countries. As a result, the costs

of preliminary studies made by an expert coming from abroad is relatively high compared with the investment cost since renewable energy power plants are often small power plants except for geothermal and for big hydro power plants.

3) Skilled technicians capable of maintaining the equipment are not available in developing countries or live too far away from the site of installation of the equipment.

Usually, as long as the exploitation of renewable sources of energy is concerned, most governments rely on private initiative to deal with investment problems. I do not know exactly why they have such an attitude, but I can very well imagine how few people living for instance in Nairobi, will agree to pay for example an initial K. Shs.50,000 ($6,000) in order to have their houses connected to the electricity distribution grid even if subsequent electricity bills will be quite low.

Now, turning to maintenance problems; it is a common characteristic of most aid agencies which intend to introduce new technologies in rural areas to request active participation of the local population and also to try and train them to maintain the equipment that these agencies have installed. Frankly, I do not think we can expect every African peasant to become a technician. Let us imagine what would be the reaction if we ourselves were asked to be able to repair a car before we could actually buy one.

Investment problems and maintenance problems in the field of classical electrical energy production have been solved in most countries by setting up a national company which deals with problems and which sells energy to consumers. Therefore the question arises : Why do governments not set up similar companies which would be in charge of the exploitation of renewable sources of energy on a national scale?

Such a public company in any African country could, right now install equipment which is readily available at costs competitive with those of diesel plants in remote areas and, sometimes, in urban areas, as it is the case for solar water heaters.

This equipment appears to be :

- Solar water heaters
- Micro hydro power plant
- Hydraulic ram
- Multiblade wind mills for pumping and in some cases wind generators
- Biodigesters to produce methane gas for cooking, lighting and to run generators as well as to produce good quality fertilisers

It should be noted that now at Fort Therman 3/ a farmer through the use of biodigesters, has been producing for the last 24 years all the energy and fertiliser that he needs for his own consumption. 4/

Also, since solar cells are now available 5) in $ 4 per peak watt, small power solar cell systems could be used not only for radio retransmitters or for cathodic protection devices but also for lighting purposes in remote houses and for remote water pumping stations.

In order to benefit from discount price through large orders, a national company in charge of the exploitation of renewable sources of energy will :

Create a sizeable local market which can convince local industries to manufacture products such as solar heaters, electrical storage batteries, methane gas holders, methane gas stoves etc. Also it will be possible to assemble solar cell panels.

If the national company finds that the equipment designed by local research teams is useful, the company could request a local industry to manufacture it. I know, from personal experience, that is the only opportunity to have such locally designed equipment manufactured.

Anot her advantage is that it would be possible through the commercial activities of the company exploiting renewable sources of energy to have a continuous insight into the needs of the people which could eventually be satisfied by the means of renewable sources of energy.

As a last word, I would say that such an organism should not be a division of an existing company producing electricity through a large thermal or hydro generating plant because the engineers and planners working in such a centralised system cannot think in terms of a decentralised system which is essential to exploit renewable sources of energy.

ENERGY DEMAND AND CONSERVATION IN KENYA

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SUMMARY

An analysis is made of commercial energy demand in Kenya. By "commercial" we restrict ourselves to the use of fossil fuels and electricity in the industrial, business, residential, and transporation sectors. It is widely recognized, of course, that many of the most pressing energy needs in Kenya revolve around problems with energy sources that fall outside of this group. Nevertheless understanding of present commercial energy demand, as well as growth, is key to the success of any country's energy policies.

To characterize energy demand, we first break down economic activity as well as physical measures, such as tons of product or square meters of floor space. Then energy intensities of these activities are examined. Using this scheme we can characterize present day energy demand in Kenya.

To build a model for forecasting of energy demand, we examine important trends in the growth of key activities analyzed above. These are paired to energy intensities that are typical of today's use or called forth by economic energy conservation practices. In this way a forecast of energy demand is built from the bottom up. In the process of the analysis we report on important energy conservation efforts in Kenya that have been brought to our attention.

INTRODUCTION

There has been much concern over the energy and development needs of the majority of the world's citizens who live in so-called "developing countries". Some of this concern has focused on the energy and environmental problems faced by the rural poor in these countries, as well as those of the growing number of substinence urban poor. Much of their energy supply is of a non-commercial, renewable sort. In this paper, however, we will examine a part of the energy consumption picture more prominent in official statistics, that of commercial energy use. We will depart from the usual analyses of commercial energy <u>supply</u> options and instead discuss in detail the nature of energy demand in a growing country. We will examine where possible the extent to which energy conservation can be practiced or is being practiced, and show how planners might use the kind of information we develop herein for modelling future energy needs.

KENYA: AN ENERGY OVERVIEW

The Kenya Bureau of Statistics has supplied the International Energy Agency with vital data on the supplies of energy during the past 14 years. Missing from these data—but discussed by other researchers is information on non-commercial fuels: wood and charcoal, dung, waste paper, agricultural wastes, and even solar energy. We have been able to estimate part of the impact of the use of solar energy in Kenya, and do so below in discussing end use of energy. The basic energy supply balance for Kenya is shown in Table 1.

The demand for energy has been heretofore studied only in the aggregate. It is clear, for example, that a country like Kenya relies very little on space heating, and under certain circumstances, need not indulge very heavily in air conditioning except at the coast. Other end use demands can be roughly estimated from known output of the East African Oil Refinery (EAOR) as well as net imports of oil products. Electric power usage is controlled principally by the East African Power and Light Company, and aggregated data on sales have always been generally available.

In this research, however, we take a more detailed approach to accounting for energy end uses. Following earlier work (Schipper and Lichtenberg, 1976), we dissagregate important energy end uses into various economic or physical activity levels (miles driven, tons produced, households) and into energy intensities (joules/mile, joules/ton, kWh/household). To do this to pay particular attention to the economic and demographic structure of the country: How many autos are there, and how far are they driven? How much steel is produced by individual plants, at what energy intensity? How many people visit a given hotel in a given year? In this way we can relate energy demands to specific economic activities that are often directly related to the degree of economic development in Kenya, particularly in the cities.

Ultimately our work should lead us to know how much energy it takes to support a variety of key production and service activities, or provide for a variety of important consumer end use amenities, such as hot water. At this stage in our research, we have <u>not</u> completely disaggregated either economic and private activities or energy use into a suitable number of categories. What we report here, however, is the progress we have made so far in accounting for energy uses of commercial energy in Kenya.

DATA SOURCES

In addition to officially published statistics, we relied on a certain number of key institutions for data. Oil companies, the Eastern African Power and Light (EAPL), architectural engineering firms, industrial plant engineers who were interviewed, producers of solar heating equipment, and transportation experts all provided data, which we reference whenever possible (and not proprietary). Our interviews led us to discuss energy use with fifteen of the largest industrial firms in Kenya, representing production of steel, paper, cement, foodstuffs, beer, trucks, tyres and energy itself— the oil refinery and the Kenya Pipeline.

Table 1. All Units GWh = 10^6kWh

Primary Supplies	Transformation: Losses*	Transformation: Net Available	Uses: Res.	Bldgs. com.	Lg. Indus.	Auto	Truck, Bus	Rail	Air	Marine Other
Electricity hydro, incl. import 1060, thermal elec. 350	200	1210	304	313	638**					
Coal 360 Other (bagasse) 700										
Oil crude+prod. 34500 - exports, stock 15800 Net 18700	1200	17500								
Lighting, cooking kerosene		750								
LPG (bulk) (cylinders)		(187)	(-90———)	(-97———)						
Motor spirit Reg. Prem.		3146				3146				
Diesel Fuel Gas Oil Heavy		3550 380				(-1440———)	(-571———)			
Jet Fuels, AV Gas		3442							3442	
Heavy Oils		6020		(-3520———)				1050		1450 El.Gen
Total (do not add vertically)										

* Losses. 1,200 GWh oil + 40 GWh elec. (both used in EAOR); transmission losses, unaccounted from elec. sectors; 1530 GWh oil consumed to produce 350 GWh thermal electricity; 50 GWh self generation, 40 GWh to EAOR.

** Includes some industrial use.

Notes for Table 1: We have given here the approximate allocation of various energy forms to various end use sectors. Figures in parentheses should not be added to row or column totals as they are composite figures. Information from EAPL, the Bureau of Statistics, the Oil Companies and the International Energy Agency was not always easy to reconcile particularly in view of the many different units, both energy and quantity, employed by various organizations. We counted the contribution of hydro power at its direct thermal equivalent, rather than counting it as if made in thermal powerplants, the IEA convention. We used an average value for the energy content of a ton of oil product, typically there should be a 15% variation from this average at the most. For LPG (Liquid Petroleum Gas) however we took its true energy value per KG, 13.4kwh or about 4 x 10^6BTU/barrel. One barrel contains by definition 42 US gallons or about 160 litres, and a standard of oil holds 5.8 x 10^6BTU. Note that we have accounted for the use of electri-

Notes for Table 1 (cont'd)

city by refining under "industry" while crude oil lost in refining appears under losses. Losses of oil in the conversion to electricity appear under the "other" column. Unfortunately the various statistics provided by the Government do not break down oil use satisfactorily for us to be able to allocate each type of product to each use. Thus "industrial and commercial uses" of oil products as given by the 1978 Survey of energy use by the Bureau of Statistics does not tell which kinds of oils were used for which activities.

In the residential/commercial data we have obtained data on energy use for hospitals, schools, hotels, and individual homes whose occupants live at very different income levels. While it could be argued that the small size of the data base for each class of user leads to high risks of unrepresentative sampling, the small number of large energy users in the country as a whole leaves us with no choice. Moreover it is possible to check consumption data with billings for the consumer provided by the energy supplier and so forth, so that some validation is possible. At present we are awaiting a programming of the EAPL billing data base that will provide us with a more meaningful allocation of electricity to individual economic sectors, rather than to individual customers.

Why should developing countries worry about energy efficiency and conservation? It is often argued that their per capita use among those people and institutions coupled to the market economics so little, that there is literally nothing to conserve. Thus no one was concerned. We found the opposite to be the case. Many factory managers and buildings experts were concerned about the cost of energy. Government officials and oil company planners as well were worried about the cost to Kenya of importing increasing amounts of increasingly expensive oil. Ironically the EAOR was a profitable earner of export dollars before the embargo, since a large portion of the crude refined there was reexported, the profits paying for the net outflow of hard currency to buy all the crude. The Oil embargo and subsequent price rise changed that situation.

The other important concern voiced in Kenya is over the commercial non-commercial interface among energy supplies. Most world statistics only count commercially—sold energy, particularly that used in activities that are accounted for in the nominal GNP. Of course there is intense competition among these two kinds of energy sources - deforestation and high cost charcoal may make commercial gas cylinders or solar looking the only viable option for rural families who cook; low cost commercially sold wood replaced oil (until recently) in one of the manufacturing firms we visited; bark could serve as a firing fuel for the paper mill, except that it proved to be cheaper in the past to debark trees where they were cut, by hand, and leave the residue behind. Oil is used instead to raise steam at the mill. Ultimately, then, there is much interaction and potential substitution among commercial and non-commercial or renewable energy sources. The problem is just that the average Kenyan, whether rural or urban, has little income with which to buy equipment that would make electric or gas cooking possible; has little choice in how efficient higher cost wood is turned into charcoal, and must interact with a market economy that is more or less dependent upon the inflow of commercial imported oil for its health. Better understanding of the efficiency of end use energy in Kenya, and recognition of the many ways in which commercial and non-commercial energy sources, efficiently deployed, could complement each other, may be the key to Kenya's energy future. For as oil prices rise, internationally, Kenya, like the countries of the OECD, may find that as all other energy sources are also rising in cost the most effective weapon against these costs remains energy conservation, the effective use of all forms of energy.

INDUSTRIAL ENERGY USE

There exists to date no detailed surveys by firm or product of industrial energy use in Kenya. However, we found very quickly that the requisite data exist, given the relatively small number of firms listed in the Directory of Industries (1974 and 1977 editions). We did not have time to survey electricity and fuel use of each type of producer, but were able to sample data from individual firms, oil companies, and East African Power and Light. Finally, we conducted on-site interviews with engineers responsible for heat and power in over a dozen important firms. Eventually we plan to completely classify energy use in Kenyan industries, and measure energy intensities, and thereby the potential for increased energy efficiency in industry.

The picture of conservation we observed in our interviews is similar to that in industrialized countries. The most energy intensive firms, (cement, refined petroleum products, paper), were very aware of the possibilities to save energy. The East African Oil Refinery has reduced the effective energy cost of producing a barrel of product; Pan African Paper Mills uses a cogenerating heat and power system in their mill; both cement producers have reduced the average energy cost of a ton of cement during the last decade.

Among other users, however, the outlook for conservation was mixed. We found one firm where the engineers complained that no one would spend a small amount to fix obvious leaks, improve boiler efficiency, or "optimize" a process, even if the proceeds for such investments were large. An engineer at a metal processing firm told us he was happy if the equipment would simply work at start-up.

On the other hand, a major tyre manufacturer pointed out that their factory has reduced energy intensities, taking part in a world wide competition among other firms owned by the same parent company. A manufacturer of food and household items, (like detergents), has just hired an engineer who plans to make important process modifications to reduce energy use; in addition this firm is eliminating the use of firewood. Firewood to them was cheaper than oil, while scarce to rural people who can't use oil anyway. Government policy now aims to conserve wood for uses other than process heat.

Included in the section in industry is the Kenya Oil Pipeline, which supplies the Nairobi area from Mombasa with around 1.2 million tons of oil each year. We obtained from the Pipeline Company their pumping energy consumption, given on a per cubic metre basis in Table 2. Additionally, we estimate the amount of fuel required to haul a ton of oil uphill from Mombasa to Nairobi, and return the empty lorry. Using data from a report from the Oak Ridge National Laboratory we estimate the energy intensity of tanker transport from U.S. data to be around 2000BTU/Ton mile (certainly a lower limit for Kenya), using a round trip of 500 miles, we found that the consumption of oil for this mode was around 20 times greater than the consumption of electricity for pumping a given quantity of oil. Moreoever, the presence of tankers on the road, as many as 150 each day leaving Mombasa, a similar number returning from Nairobi, creates problems for traffic on the road and apparently serious problems for the road surface. While the pipeline certainly has impacts that we have overlooked, these environmental and energy advantages cannot be dismissed.

What of the tanker drivers who might now be unemployed? This is a problem that surfaces in every country as energy development proceeds. However, one of us (LS) observed a yard in Mombasa where the tanks were being removed from tankers that were then converted to flatbead trucks. This suggests that the impacts of energy development can be mitigated, given time and careful planning.

How should Kenyans view energy conservation in industry? Simply as a way of cutting costs, and therefore increasing overall productivity. This is extremely important, because of the likely increase in world oil prices. Moreoever heavy industry energy needs are dominated by process heat, not by labour saving electricity. In smaller shops or assembly firms electricity is proportionally much more important, but usually only a small fraction of total production costs. Therefore conservation will not threaten the productive use of labour and machinery.

For forecasting purposes our methodology can be applied by looking at energy intensities (Btu of fuel, kWh of electricity per ton of output) in all process industries, spotting trends that tend to reduce specific fuel use and possibly increase slightly specific electric use. We forecast future demands based upon this physical measure of use and output. EAPL forecasts output based upon applications from industries for increased or new connections, noting both demand and total electricity purchased. We recommend that wherever intensities are not closely examined they be so; firms planning to expand should in their plans relate specific energy intensities and expected output to the demand of the plant expansion; corporations, especially multinationals with access to the latest, most energy efficient technologies, should be encouraged to employ such technologies in Kenya. (We found evidence of this already.) Reporting of yearly fuel and power use related to each kind of major product made by every large energy user might be made mandatory, as is the case in the United States. This affords officials the chance to spot progress in conservation and encourage those firms that have done little to do more. By all this we do not mean to imply that energy be saved for its own sake; only that opportunities to save energy and money, now overlooked, be exploited. There exists abundant evidence that such was the case in developed countries for many years.

Table 2. Some Industrial Intensities

Type	Place	Electricity	Fuel	Output Unit	Year
Lorries	Kenya	173.4KWh	1.85×10^6 BTU	Lorry	1978
Beer	Kenya	.12 KWh	2200 BTU	Litre	1978
Tyres	Kenya	1.09 KWh	15000 BTU	Pound of tyre	1975
	Kenya	.74 KWh	9650 BTU		1978
	World average, same company		13,400 BTU (total)		
	U.K., same company		19,000 BTU (total)		
	S. America, same company		11,100 BTU (total)		
Oil Refining	Kenya	16 KWh	1.48×10^6 BTU	Ton	1977
		11.5 KWh	1.37×10^6 BTU	Ton	1973
	Typical refinery, 20% gasoline, 3.75×10^6 T/yr		1.75×10^6 BTU/ton		
Steel	Kenya				
Scrap Melt		667 KWh	0.64×10^6 BTU	Ton	1977
Rolling		200 KWh	3.9×10^6 BTU	Ton	
Cement	(1)	90 KWh +	6.0×10^6 BTU (same plant)	Ton	1975
	(2)	90 KWh +	5.3×10^6 BTU		1977
3 processes in 2 plants	(2)	105 KWh +	3.1×10^6 BTU (same plant in different kiln)		1977
	(3)	95 KWh +	3.6×10^6 BTU		1977
Other countries	South America	-	4.5×10^6 BTU	Total	1978
	Sweden	-	4.8×10^6 BTU	Total	1975
Paper cogeneration	Kenya	-	5.1×10^7 BTU	Total	1977
	Sweden	-	3×10^7 BTU	Total	1973
Kenya Pipeline	Kenya	-	10 KWh or 870 BTU	Cubic meter 10^6 BTU of oil	DATA
	Lorry Mombasa-Nairobi		15,400 BTU	10^6 BTU	ESTIMATE

Note: These figures were obtained directly from represenative firms. Where possible we give the electricity-fuel breakdown. The comparative figures have electricity figured in, in the case of tyres electricity is counted at 10000 BTU/kWh. Note in some cases we give figures.

One area of policy that influences total energy use is that relating to combined generation of electricity and heat. Currently firms are allowed to cogenerate their own power and heat together, saving considerable energy (and money); relative to separate generation. But only one non agricultural firm does this, Pan African Paper Mills, and they are not allowed to sell extra electricity back to EAPL or to other possible customers. This practice, which has also encountered similar difficulties in the past in the U.S., nevertheless promises great energy savings whenever EAPL otherwise would be forced to install thermal based electric generating capacity. (The Honakaa sugar mill in Hawaii has such an arrangement.) Since economic forecasts do call for rapid expansion of heavy industry in Kenya, the prospects for meaningful savings from utility-industry cooperation are great. One possibility is to give EAPL the authority to construct the power and heat station at the site of the industry.

Under present rules, however, cogeneration appears to be discouraged. For example, one firm that plans a major expansion of their production, intends to install only steam/heat producing equipment. The most economical size of cogeneration plant for them would meet far more than their needs of electric power, for which there would be no market today. The system that would meet their electric power needs appears to be too expensive per unit of output, because of its small size.

We are not necessarily proposing here to revamp a complicated set of laws governing the production of electric power. Still, we have seen from all parties concerned invariably results in greater cogeneration and a large savings in energy and all resources for the country. Thus we recommend a review of the possibilities for cogeneration in Kenya.

Table 2 gives an overview of energy intensities in Key firms. For some several years data are given, or comparative figures from other parts of the world. The East African Oil Refinery increased its size after 1973 but did not increase output. Consequently efficiency fell. A conservation program gained back some of these losses. As output increases the energy intensity will fall again. Firms that have indicated major expansion plans to EAPL include those producing steel products, glass, cement, fertilizer, food, and chemicals. Given the rapid pace of growth of industry in Kenya, we expect to see new technologies in process industries that will allow output to increase considerably faster than energy use, particularly as energy prices rise.

COMMERCIAL BUILDINGS

Commercial buildings include many kinds of enterprises; the most important for Kenya are public services (schools, hospitals), hotels and restaurants, office buildings (including government) and stores. Most of these are classified under the old EAPL tariff system into Tariff 3 and 4. Similarly some of the classes of users are broken out from overall oil company data; where possible we indicate (Table 3) how much total energy goes to various sectors.

We have gone further by using estimates of building energy use for key kinds of buildings; major hotels, office buildings, schools, hospitals. Some of these buildings are described in Table 4. In the case of one major hotel, we found that overall electric power use per guest per year had been decreased substantially from 1976 to 1978, in part due to the recent initiation of a conservation campaign.

On the other hand, energy use in large structures in Kenya depends critically on the building shell design. Most, but not all of the new office buildings in Nairobi, for example, exhibit elaborate systems of shading to keep direct sunlight off the windows. Energy conserving buildings have their axes oriented east-west, with few windows on the east-west ends and shading on the north-south sides. This design maximizes free (day) light, minimizes cooling needs (if any) and only sometimes requires the use of small electric heaters in some rooms during cold months. We have not yet surveyed lighting levels in offices but we found no evidence of the overlighting often found in the U.S.

For forecasting purposes we would recommend that projections of building space by type of building and region be used in conjunction with more detailed surveys of energy use per square meter in these types of buildings. In this way a detailed bottom-up forecast of energy demands can be made. Particular attention must be paid to the use of commercially sold fossil fuels for cooking and hot water vs electric or solar hot water. While it would be difficult for the government to require solar hot water, the economics are attractive, and government encouragement (vis a vis electric or fossil fuels) through taxes might be a possibility. On the other hand it might be entirely possible for the government to mandate prudent, well understood, but profitable energy conserving designs in all buildings as a condition of granting building permission; proper shading, use of economizer air circulation cycles, building orientation, and related measures can cut energy use in buildings dramatically. This offers great opportunities for Kenya based architects and engineers who can design and run these buildings with full knowledge of the climate and sun in Kenya, as opposed to buildings designed outside of Kenya that are simply lighted and air conditioned (or heated) with no account of the climate in Kenya as a natural energy source. (We were told of a design for a major international hotel that included lavish use of air conditioning, not because the climate demanded it, but because all other hotels in this chain had air conditioning! The hotel was never built.)

We examined the penetration of solar water heating, and mentioned some examples above. We find that solar water heating has an enormous potential in Kenya in virtually all buildings where hot water is important.

Table 3. Provisional Breakdown; Other Electricity Uses

	Customers	Price/kWh Ke cents	Total Sector kWh	Remarks
Commercial small[a] (T3)	20,000	55	132×10^6	1976
large[b] (T4)	400	55	140×10^6	1976
Large Industry (T5)	490	27.3	356×10^6	1976
Agriculture[c] Nairobi	50		13×10^6	
(Large		40		
Estates) Elsewhere	50		35×10^6	
Nairobi only				
Total T4	251	-	95×10^6	1977
	270		103×10^6	1978
among which....				
Hotels	24	35	19.6×10^6	1977
	25	45	14.4×10^6	1978
(coastal region)	40	-	23.9×10^6	1978
Hospitals			15.7×10^6	1977
			11.8×10^6	1978
Offices, Banks (excluding government)	22	50	11.4×10^6	1977
	22	60	12.6×10^6	1978
(New customers only)	3	60	1.9×10^6	1978
Kenyatta Centre			2.7×10^6	1977
		33	2.2×10^6	1978

a Mostly shops

b Mostly large buildings, schools, some light manufacturing

c Agriculture includes farms and estates; totals included in T4 and T5

Table 4. Some Key Buildings

	Major Hotel	Nairobi	Air Conditioned
	Electrical kWh/Guest	Oil BTU/Guest	Gas BTU/Guest
1976	37.5	3×10^5	-
1977	35.5	2.9×10^5	2×10^2
1978	29.4	2.9×10^5	2×10^2

HOMES

Energy use in the residential sector is characterized by extreme concentration into a small fraction of all households. As the figures in Table 5 suggest, only 6% of the population in Nairobi, and less elsewhere, was "connected" to East African Power and Light grid. Complementing this picture is the relatively minor use of kerosene for lighting and cooking and the somewhat greater use of cooking as cylinders.

The majority of Kenyans, of course, use charcoal or firewood for domestic purposes.

We have been able to breakdown electricity use further, using data from EAPL. The largest residential consumers register their hot-water electricity consumption on a special tariff (with an electronic signal interrupter). In 1976 there were 27,000 hot water customers, 51,000 regular residential customers (including the hot water) and 56,000 customers using very little-if-any-electricity. Many of these live in rural areas or in low-income estates. Typical figures for consumption in these groups are given in Table 6. It should be noted that the designated income group for each housing tract does not **always** reflect the incomes of the people who actually live there, due to sub-leasing. Similarly great use by wealthy households includes servants' quarters.

What is missing from this electricity use picture is the complimentary use of fuels. While electric cooking probably dominates in those homes with Tariff 1 or 6, it is clearly absent from those on Tariff 2, charcoal or in some cases gas being more important. One house we visited has switched from gas to charcoal since the gas stove exploded. Total sales of gas cylinders were approximately 4×10^5 BTU in 1978.

For forecasting purposes, one needs to know approximately how available cooking charcoal will continue to be for urban dwellers, as well as how fast incomes among low income families might increase. The latter is important because of the high capital cost of electric or gas stoves. (Typically a 2 burner electric stove may cost $400, a refrigerator as much.) Moreoever, the chances for increased electrification of housing projects depends, from the utility's perspective, on the prospects for selling kWh in the long run.

The prospects for solar water heating in Kenya are bright. We examined the records of one of the major assemblers and suppliers of solar water heaters. Using an estimate of 2000M^2 of collector installed thus far, each M^2 providing about 9,000 BTU/day of hot water, we find that installed residential and commercial hot water systems save Kenya about 1.5×10^6 kWh/year that would have been required in the form of electricity for heating this water. Moreover, a great deal of this electricity would be under normal commercial tariff, being used in schools or hospitals. The total investment cost for these collectors has been approximately 3×10^6 KS.

Table 5. Residential Energy, 1978*

	Customers	Price, KeC	Use/yr.kWh
Regular electricity	51,000	33	3,000 per customer
Small users (elect.)	56,000	125	250
Hot water (elect.)	22,000	18	4,815
Gas cylinders			
Cooking and lighting Oil	-	-	-

* Data are incomplete but it is anticipated that the missing information will become available soon, especially regarding the number of dwellings using fuels and the average consumption per person or per dwelling.

Table 6. Residential Electricity by Income, 1977

Description	Sample Size	Avg for six months			Tariff
"Lower Class Estate"	20	10 kWh/mo			T2
"Middle Class Estate"	12	258	"		T1
Executive Housing	12	565	"	Normal	T1
	11	444	"	Hot water	T6
Large Estates	18	752	"	Normal	T1
	17	462	"	Hot water	T6

Samples of Electricity Billing Data. The description of the housing are only approximate and reflect the outward appearance or purpose of the housing project. Note that the last two samples reflect hot water and cooking for servants. In Nairobi roughly half of all customers receive Tarrif one and or six, the normal and hot water tariffs, while half receive Tariff T2. The average for "middle class estate" probably should be used for forecasting purposes. Data source: EAPL. See also McGranahan, et al. elsewhere in this conference.

For prices, see Table 5 and 10.

If normal tariff electricity costs 50 cents/kWh, then the yearly savings to Kenya from this investment is approximately 750,000 KS*. The solar manufacturer we interviewed pointed out that business was booming, and provided us with the examples of new projects (a school, a hospital, a condominium) that he expects to complete soon (Table 7).

Where might Kenya save residential energy? First, by ensuring that appliances imported and or sold in Kenya meet minimum efficiency standards; second, encouraging the use of solar hot water heating; third, ensuring that public housing incorporates passive solar energy features, to minimize if not eliminate the need for heating and cooling away from the coast. While space heating is not important in most of Kenya, it could become important as incomes rise. But it appears that proper design of residential structures would eliminate most of this need.

Competing with commercially sold energy, as we pointed out above, is the use of wood, charcoal, and other renewable fuels for cooking and possible water heating. Unlike electricity, these fuels (and gas cylinders) are available in the rural regions; thus the choice between them and electricity tends to be biased because of the cost of electrifying villages. That is, both non-commercial fuels and electricity (or gas plus the necessary stove) are scarce resources, if for different reasons. This means that the choice between them, if there is to be a policy favouring one or the other, is difficult.

TRANSPORTATION

Statistics on transportation are often well known in the aggregate, because motor vehicles are registered, traffic is often surveyed, and most motor fuels are taxed in one way or another. On the other hand there are many ways in which sales of fuels do not correspond uniquely to one class of vehicles, or where types of vehicles may provide two kinds of service. Light Diesel fuel, called Gasoil, can fuel automobiles or light trucks; heavy diesel fuel can fuel trucks, railway, or some buses. Matatu usually run on motor gasoline, but ordinary trucks can be used as matatu. Thus it is difficult to assign fuel use to specific tasks, and therefore difficult to analyse the fuel efficiency of each vehicle or service.

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* This calculation assumes no standby losses for either system, and we count only the hot water actually made available by solar systems. If all this were produced from the low cost interruptible tariff the savings would be considerably less, of the order of 300,000 KS per year. Either way the rate of return is greater than 10%.

Table 7. Solar Water Heating*

Type of building	Investment	M^2	Electricity Replaced yearly	Cost**
Group of 42 flats	360,000 KS (8600 KS/Flat)	112	4000 kWh/flat	32¢
Luxury condominium	510,000 KS (5000 KS/flat)	250	3000 kWh/flat	25¢
School, 300 students	100,000 KS	38		(50 KS/student)
Medical Centre (80% solar)	330,000 KS	128		

Netherless we give the breakdown of fuels used for transportation, and their end uses, in Table 1. In Table 8 we present another view of transportation, the share of vehicles in each class and the share of vehicle miles in each class as estimated from actual road surveys.*** In general the following rules apply relating vehicle type to fuel:

Private cars-up to nine passenger vehicles except Landrovers and minibuses: using premium fuel.

Medium commercial vehicles-two axled goods vehicles weighing more than 1524 kg. with more than one tyre in each axle: regular fuel.

Light commercial-as above, but less than 1525 kg: regular fuel.

Heavy commercial-more than two axles, using diesel fuel.

Bus-other passenger vehicles including minibuses, including dual purpose vehicles: using diesel fuel (except matatu).

Note that the share of vehicles in each class roughly corresponds to the share of vehicle miles in each class. That commercially motivated vehicle miles exceed that classification's share of vehicles, when compared with private vehicles is not surprising; owners of capital, such as vehicles, try to maximize the utilization of their often sub-

* Beasley collectors produce about 17,000 BTU/day/M^2 hot water 32 litres/day with 80°F temperature rise. Other supplies in Kenya have not been surveyed. Data from K. Mousley, Instrumentation Ltd., Nairobi and Beasley, Ltd., Australia, fact sheets.

** Cost estimated as ratio of 15%/annum fixed charge to electricity produced, i.e. ¢/kWh.

*** These figures do not truly represent vehicle miles, but we use them as a proxy for the rough division of traffic into various classes or modes.

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Table 8. Amount of travel by class of road and vehicle type, 1978

(In 000's Km)

Class of Roads	% of Total Network[1]	Average yearly vehicle traffic per kilometre of road class (Veh/Km.)						
		Cars	Light Commercial Vehicles	Medium Commercial Vehicles	Heavy Commercial Vehicles	Buses	Total (Veh/Km)	(%)
Trunk	13	1,185	886	501	178	220	2,970	(62)
Primary	18	339	553	300	12	71	1,275	(27)
Secondary	23	71	258	95	1	53	478	(10)
Minor	46	1	8	2	-	-	11	(1)
All roads	100	1,596	1,705	898	191	344	4,734	(100)
Percent Veh/Km.	-	(34)	(36)	(19)	(4)	(7)	(100)	-

1 Excludes Special Purpose Roads.

Source: Development Plan 1979–1983

stantial investments. On the other hand, most developed countries reveal clear patterns of growth: use of private automobiles rises somewhat faster to much faster than private incomes, while use of commercial vehicles, particularly for freight, tends to scale only with total output. Armed with more detailed fuel sales statistics we could closely couple fuel and efficiency to transportation services.

We now couple to the greatest extent possible the use of energy to the activities of transportation. In Table 9 some of these relationships are shown. First we show the number of passengers actually embarking from Nairobi International Airport for international destinations, and the amount of fuel loaded there. While this measure of efficiency, fuel use per passenger, is crude, its decrease during a period when additional transcontinental flights from Europe and Africa were being added to schedules, thus lengthening the average trip away from Nairobi, suggests conservation. In fact the 1973-77 era saw the replacement of most narrow bodied aircraft by more fuel efficient aircraft, and an increase in charter flights from Europe. These changes increase energy efficiency. On the other hand, emergency conditions often dictate that planes cannot take on a full load of fuel in Nairobi, but must bring in fuel. Therefore the figures must be seen as provisional until surveys are arranged to show the exact amount of fuel used in Kenya to transport a passenger—whether a Kenyan or a tourist returning home—to an overseas destination.

In the case of private autos, we give amounts of gasoline sold to autos as well as the number of autos registered. This gives an approximate measure of intensity of use, though not efficiency, since we have not obtained data on actual miles travelled, nor on auto weigh or load factor. Moreover we do not include the use of gasoil (diesel fuel) for autos alone. However we suspect that a few surveys among auto dealers, registration statistics, and fuel sales records would reveal many of these measures. We hardly need to point out the phenomenal growth in the ownership of autos. In Figures 1 and 2 some of these data for cars are displayed.

Finally we give a measure of the use of trucks and buses in the Table, showing also fuel used. Here we take the sales of gasoil as reported by Kenya Shell, since the official statistical abstract lists "light diesel fuel" that is also used for some stationary applications. We give this figure separately but warn against any strict interpretation of these figures.

There are other important uses of fuel that we have not covered here. Among those are inland and overseas shipping, exact use of energy for passenger and freight rail, exact use of energy for buses, and use of energy for matatu. It is believed, however, that much of this information could be obtained in future interviews with the private companies running the services and those providing the fuel. Taken together, all this transportation data, combined with economic and demographic projections of incomes, mobility, and location of people, would provide an excellent base for a careful forecast of energy demands for future transportation in Kenya.

Table 9. Some Transportation Energy Uses

	Activity Passengers	Gross Energy	Intensity
Jet Aviation (Nairobi only)			kWh/passenger
1973	730,000	3570 GWH	48.2
1974	790,000	3540	44.2
1975	920,000	4020	43.1
1976	960,000	4140	42.5
1977	-	3860	42.5 assuming increase in traffic
1978	-	3800	42.5

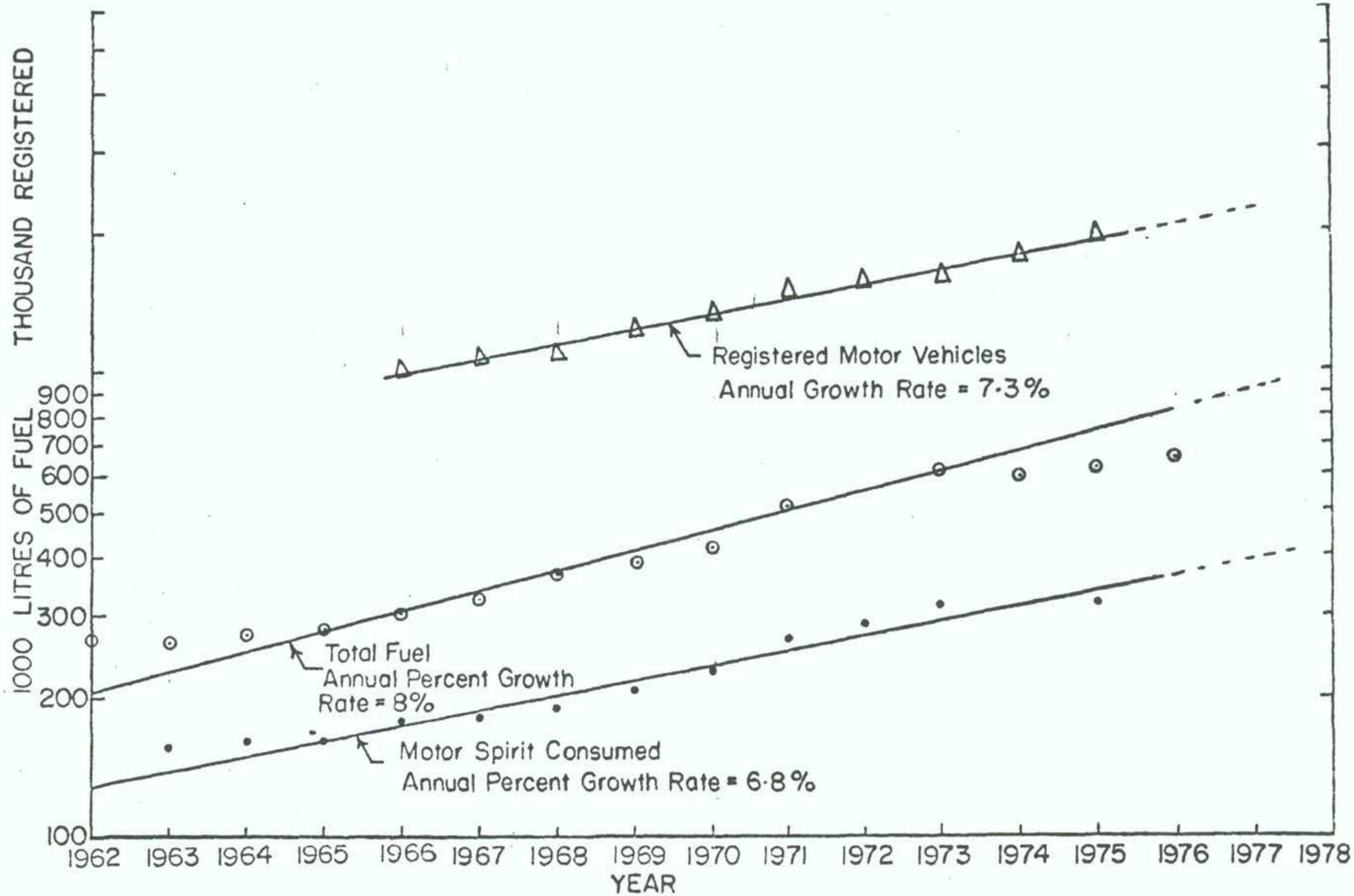
Source: Statistical Abstract, Kenya Shell.

Private Autos	Registrations[a]	(a) Gross Energy[b]		
1973	70,660	2710 GWH	3106 GWH	-
1974	78,300	2625 GWH	3015 GWH	-
1975	83,680	2730 GWH	3145 GWH	-
1976	88,700	2800 GWH	3230 GWH	-
1977		3150 GWH		
		3250 GWH		

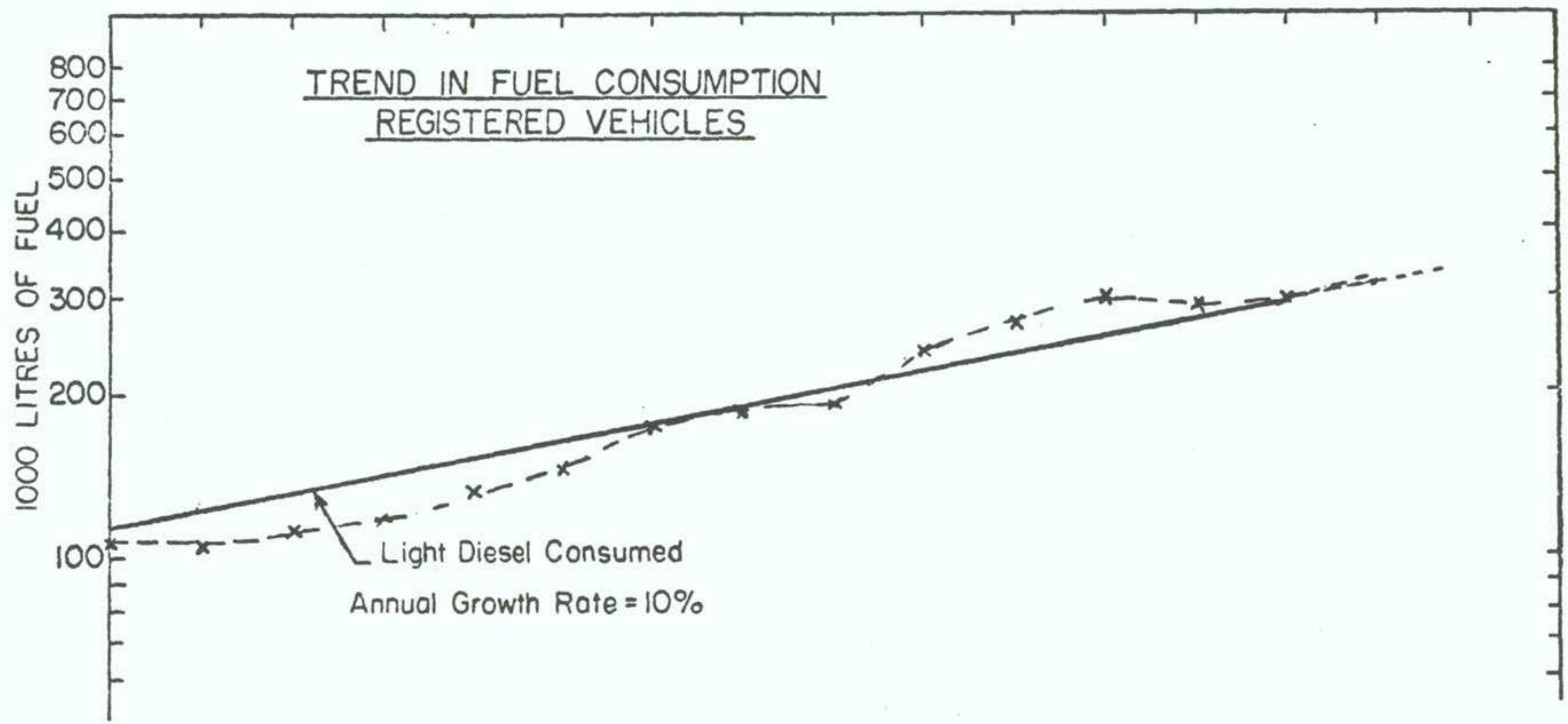
Source: Bureau of Statistics, "Statistics of Energy and Power" for (a) Statistical Abstract for Registrations, Gross Energy (b) which may include gasoil.

Other Trucks Buses	Registration(a)	(a)	(b)	(c)
1973	67,750	2950 GWH	3250 GWH	-
1974	76,460	2910 GWH	3120 GWH	1220 GWH
1975	83,825	2965 GWH	3260 GWH	1250 GWH
1976	91,790	3350 GWH	3660 GWH	1360 GWH
1977	-	3550 GWH		1490 GWH
1978	-	-	-	-

Source: As above. (c) Kenya Shell Gasoil Figures. Differences due to definition of product; do not always reconcile with Table 1.



Fg. 1. Growth in the use of automobiles and fuel in Kenya.



Fg. 2. Growth in the use of light diesel fuel in KEnya. Light diesel includes "gasoil" and diesel fuel for trucks.

ENERGY PRICES

The increase in world energy prices was felt in Kenya. First, the East African Refinery, which used to turn a foreign exchange profit by reselling oil products amounting to about half of the throughput of the refinery, saw foreign demand drop off somewhat, the domestic share increasing. Worse the gross profit margin on a unit of product became very small in relation to the price of crude. Thus the situation after 1974 was very different than in 1973 and earlier.

In Table 10 we present some representative energy prices in Kenya, from data gathered by Bikro Consult, Kenya, and from the Bureau of Statistics. We have converted all amounts to units of 10^6 BTU or kilowatt hours. We remind readers that transportation charges for fuel, and demand charges for heavy electric power users must be added to these figures.

The data presented are in current KS. While the price increases seem dramatic, the GNP deflator for the period 1974-77 inclusive is approximately 1.6, according to the difference between the monetary GDP in constant and current dollars as given in the 1978 Economic Survey. We give the approximate value of these fuels in 1974 prices, and the change is dramatic. While basic fuel prices, with the exception of LPG, have increased considerably, electricity prices have not, due of course to the dominance of hydropower in the supply picture. On the other hand, preliminary data from 1978 indicate that substantial price increases over 1977 occurred, and a new billing system and tariff was introduced in 1979.

While we do not calculate elasticities here (we refer to the paper by House and Killick) we note that two factors determine the use of energy from an economic point of view. Energy prices determine in part the marginal cost of using certain equipment or enjoying certain amenities, provided the user possesses the capital equipment in the first place. Prices also play an important role in the choice of equipment particularly where solar water heating or most industrial uses are concerned. On the other hand incomes and income growth play a great role both in affordability of equipment and the ability to use that equipment. In Europe, for example, gasoline use is climbing steadily because family incomes are increasing and they are buying their first or second autos. Accordingly gasoline use will be rising there for some time in spite of high prices, though not as fast as the increase in autos, because autos in Europe may become more energy efficient now. This kind of analysis must be performed on all sectors of energy use in Kenya in order for us to be able to derive meaningful price-income-intensity of use relationships. Moreover, we must be able to measure use of commercially sold fuels in relationship to non-commercial fuels, capital intensive renewables like solar hot water, and of course the non-market income of many Kenyans. While we respect the discussion of House and McKillick, we suggest that the measurement of traditional elasticities of energy use be made with extreme care.

Table 10. Energy Prices

Units - Kenya Shillings/10^6 BTU or kWh

Fuels (KS/10^6Btu)	1973	1974	1977	1977 at 1974 prices	Remarks
Fuel Oil	14.6		39.0	24.4	FOB Nairobi
Diesel Oil (Heavy)	17.0		46.3	28.9	"
Gas Oil (light motor diesel)	24.3		61.0	38.7	"
LPG, 15 kg. cylinders	55.8		97.6	61.0	"
LPG, bulk	65.5		87.8	54.9	"
Motor gasoline	40.8	64.9	72.3		Avg. of super/ regular

Electricity ¢/kWh	1974	1976	1977	1977 at 1974 prices	
Regular domestic	25.8	35.4			
Special domestic	112.5	128.9	36.4	22.8	1977 is average for all 3 tariffs
Interruptible domestic	22.6	18.6			
Small commercial	41.5	54.8	60.0	37.5	
Large commercial	24.6	34.0	40.0	25.0	
Industrial	17.8	27.3	31.0	19.31	

We noted in several places that sites we visited indicated that energy conservation programs were in progress. In every case the person responsible cited higher prices for fuels and electricity as the primary motivation. As to our pessimism over the lack of interest on the part of some firms, it is well known from economic observations that the response to a price increase, be it steady or one-time, takes between a few and tens of years, to take effect. The reason is simply that the greatest changes in energy use take place with least cost when new equipment is built. We did notice several buildings that could be retrofitted to reduce solar gain and hence air conditioning, including the building housing the American Embassy, the Hilton Hotel, and even the Kenyatta Centre. We mention the names of these buildings not to single out their owners/managers but to show that a wide variety of enterprises could take part in energy conservation as energy prices climb. We also note that home owners can add insulation to hot water heaters (in the United States electric utilities now provide this as a service), shade windows, keep refrigerator coils clean, and make a conscious effort to reduce the number of miles driven. The Kenyan Government, EAPL, and energy suppliers might join with the Kenyan Government in making concrete suggestions for saving energy available to all Kenyans.

FOREIGN TRADE AND EMBODIED ENERGY

An extremely important source of energy often omitted from national data is the energy bound up in imports and exports. That is, a unit of goods or services required energy for its fabrication, including the process energy use to make the raw materials and so on. Elsewhere we examined the balance of trade for this embodied energy and found that while the United States imported a small amount (about 1% of its 1973 gross energy use), Sweden and other countries in Europe were significant exporters. That is, significant quantities of the oil imported by many nations leaves their borders' bound up in steel, paper, and other energy intensive goods. Agricultural products, by the way, tend not to be energy intensive on an energy/ton or energy/monetary-unit basis when compared with raw materials. One important energy intensive export from Kenya is refined oil products, energy for which is consumed at the EA Refinery. This embodied energy amounts to nearly 5% of the actual heat content of the fuels exported. Another may soon be paper.

We have not evaluated specific energy intensities for the many materials and products that Kenya deals with. However, we note that three significant categories besides trade in actual fuels show a great import surplus: These are industrial supplies besides food, machinery and other capital equipment, and transport equipment. These are listed here in the approximate order of greatest to least energy intensity. In 1974 these goods amounts to 240 x 10^6 K£ imports, 85 x 10^6 K£ exports, and in 1977 (deflated by 1.6 to 1974 currency) 212 x 10^6 K£ imports and 56 x 10^6 K£ exports. Estimating average energy intensity for these kinds of products at about 100,000 BTU/1974 US \$ (1\$ = .35 K£ approximately) this amounts to about 40 x 10^{12} BTU in 1974 and a similar amount in 1977. These figures appear to be greater than half of the recorded energy use in Kenya. While our estimate is rough, this hidden energy is known to form a significant fraction of energy use in other countries, as much as 20% in Denmark. We expect that our estimate is correct to within a factor of two, and point out that the major export from Kenya, food products, tends to be far less energy intensive than the goods we have considered here. However it would be useful for Kenyan energy planners to look carefully into this hidden energy flow since by any account it is significant in the overall energy balance, particularly as rising world energy prices push up the costs of energy-intensive materials and products.

FURTHER ANALYSIS

We recommend that certain vital areas be treated in depth for further analysis and information. These include:

1) Energy and Tourism: What is the energy cost of foreign tourism in Kenya, including hotels, ground transportation, and fuel loadings at international airports?

2) Low energy buildings: What is the potential for further conservation in new public buildings and housing?

3) Matatu: What is the energy for this form of transportation and how does it compare with buses? To what extent would a greatly expanded public transit system obviate the need for automobiles?

4) Industrial energy use: Can a detailed survey as described herein be carried out over all heavy users of energy.

5) Commercial, non-commercial fuel interface: What is the true potential for reducing fuel imports by using non-commercial renewable fuels? What would the environmental impact of intense exploitation of renewables be? What are the measures of effective use of these fuels and their associate technologies? What is the true picture of urban or rural domestic energy use?

6) Transportation: How can careful urban planning avoid the traffic chaos that is beginning to appear in Nairobi?

CONCLUSIONS

In this brief survey of some key energy uses in Kenya we have seen that there is evidence of efficient energy use and opportunity for conservation as well. We emphasize that conservation to Kenya means more economic use of all resources, including energy, rather than economic sacrifice. We hasten to point out that the full effects of increases in world energy prices has yet to be felt in Kenya--or elsewhere for that matter--because of the time it takes for capital equipment to be modernized or updated. Nevertheless we expect that other things being equal, the coupling between increments of energy use and increments of economic activity in Kenya will be loosened in the sense that the former will proceed at a somewhat slower rate than the latter, at least relative to pre-1973 relationships. That overall energy use may grow faster than the overall economy, when only commercial energies and the money economy is counted, is primarily due to industrialization and structural change in Kenya, and should not be considered as a sign of waste. In most of the economies of the industrialized nations energy use is now expected to grow far more slowly than GDP, though the reverse was often true before and after World War Two.

REFERENCES

Central Bureau of Statistics, 1974, 77. Directory of Industries Nairobi, Kenya. See also Economic Survey, 1978.

Central Bureau of Statistics, 1978. Statistics of Energy and Power 1969-77. Nairobi, Kenya.

Schipper, L. and Lichtenberg, A., 1976. Efficient Energy Use and Well Being: The Swedish Example. Science 194, p.1001. December 3, 1976.

Estimates of industrial energy intensities from other countries taken from Schipper and Lichtenberg (Ref.2); Schipper, L., 1978. Energy Use and Conservation in Industrialized Countries (to be published in 1979) in Energy Conservation and Public Policy, J. Sawhill, editor, New York; Prentice Hall; and private communications with other researchers and firms interviewed. In each case we obtained energy intensities of firms listed directly. Sample energy intensities of goods in foreign trade are found in Schipper, L., 1976. Ann. Rev. En. 1. Palo Also:Ann.Revs. Inc.

Additional information on energy use and the economy can be found in the paper by House and Killick; on urban and residential energy use in the paper by McGranahan, et. al.; both are presented in this conference. See also "Basic Energy Statistics and Energy Balances for LDC's"; Paris, International Energy Agency, January 1978 (with updates for 1977 for Kenya supplied by the IEA).

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THE PRESENT AND FUTURE PATTERNS OF
CONSUMPTION AND PRODUCTION OF WOOD ENERGY IN KENYA

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SUMMARY

In our analysis we are concerned with the supply and demand for fuelwood in Kenya over the coming decades, and in showing on a regional basis areas of potential surplus and deficit.

To evaluate demand we have stratified the rural population into three categories: those employed on large farms, small farms, and the bulk who are subsistence agriculturalists. The demand for energy within each group is based on existing survey data which further predict the type of energy consumed according to income. From these data we projected growth in population and income for each category is used to calculate the demand for fuelwood through the year 2050.

To evaluate the available supply of fuelwood and the recurrent annual production we have, from various data sources, derived predictions from climatic data. These have enabled us to provide national and regional estimates of potential wood supply. In the calculations, the amount of land presently under agriculture, National Parks and reserves have been discounted. Using currently projected growth rates and carrying capacities for agricultural land we have further calculated the reduction of future wood supplies.

The calculations suggest that subsistence agriculturalists demand will continue to account for some 90% of fuelwood consumed over the coming seven decades. It is apparent that the demand on land for agriculture will increase enormously and will in most provinces consume the available arable land within the next 15 years. Unless changes in land use patterns are effected little fuelwood production can be anticipated from these areas which also offer the only substantial potential for wood for fuelwood. The low annual wood increment of the arid zones and the enormous economic costs of gathering and transporting fuelwood do not offer this as a significant alternative.

Projections indicate that fuelwood consumption in most provinces will exceed the annual production by 1990 and that supplies will be continuously mined from then onwards unless there are major changes in the energy policy.

INTRODUCTION

A number of studies have been undertaken to evaluate the potential supply and demand for charcoal in Kenya (Arnold et al, 1962; Chlala, 1972; Uhart, 1975; Kabagambe, 1976). In general these have only assessed the demand in urban areas and a satisfactory country-wide survey has yet to be undertaken. An even larger gap exists in our information on fuelwood demands, even though this is appreciably higher than charcoal requirements on a national scale. However a number of studies on the per capita consumption of wood amongst rural populations have been made in Kenya and elsewhere in East Africa (Arnold et al, 1962; Openshaw, 1976) but these did not calculate the country wide demand relative to supply. There is therefore an urgent need to assess the total requirements and supply of wood fuels in Kenya, to calculate what role they presently play in national energy consumption and how the pattern is likely to change in future. It is frequently argued that a greater dependence on locally produced energy sources will lessen Kenya's dependence on imported fuels, will save on foreign exchange and will create a large rural employment (Githinji, 1978). However, the extent to which internal self-sufficiency in energy can be achieved will depend substantially on the potential production of the various energy sources.

Our intention here is to examine the consumption of wood fuels in the various sectors. These include large and small farms and rural subsistence and urban domestic use. We provide an estimate of the contribution of wood fuels to the total energy consumption in Kenya, examine consumption patterns by province and project the growth in demand over the next two decades, and for the purpose of illustrating future prospects, to the year 2050. To look at the potential of wood energy to meet the existing and projected demand, we have calculated the production of wood biomass on a national and regional basis. Finally from an analysis of the patterns of supply and demand we have deduced the status of each province in terms of its surplus and deficit of wood energy, now and in the coming few decades. The factors which contribute to the increasing the efficiency of wood utility.

METHODS

In calculating the balance of wood energy we have had to make various assumptions about existing and future demand and supply of all wood fuels. We adopt two ways of examining the energy balance. The first involves calculating when the sustained yield of wood production is exceeded, the second how long the existing standing stocks will last. To calculate the existing wood consumption, we have, by province, stratified the population into various sectors which have different patterns of consumption; large farmers, small farmers, subsistence agriculturalists and urban dwellers. The wood consumption amongst each sector has been calculated on the assumptions given in the Appendix. For large and small farmers consumption is derived from Earl's (1975) data which relate both total energy use and the fraction used as wood to GNP per capita. The population figures and projections we have used have been drawn from Central Bureau of Statistics (1971, 1972).

By far the largest proportion of the population in Kenya comprises subsistence, rural agriculturalists. To estimate their wood consumption we have drawn on a variety of surveys that have estimated the present use and future demand (Table 5). By far the major proportion of the wood consumed by this sector is used as energy. This amounts to some 94% (Table 5). In our calculations we have therefore used the per capita wood fuel consumed as the basis of projecting wood demand. The actual total will therefore be slightly higher than we have projected, but will fall within the upper ($2m^3$) and lower ($1m^3$) range of consumption that we have based our projections on.

The bulk of wood fuels used in Kenya are consumed in the form of fuel-wood. However, a substantial proportion is used in the form of charcoal. Because of the low conversion efficiency of traditional charcoal kilns (about 9kg of wood are needed to produce 1 kg charcoal (Oppenshaw, 1976), the amount of wood wasted as insensible heat is extremely high. We have therefore tried to express the amount of wood consumed per capita for that proportion of the population dependent largely on charcoal. This is confined predominantly to the urban areas (Chlala, 1972; Kabagambe, 1976). To estimate the urban demand we have relied on the only source of data that apparently estimated charcoal use from direct observations. In doing so Chlala (1972) estimated that urban use ranged between 100 and 165 kg per capita per annum. Almost all publications since 1972 have relied directly or indirectly on Chlala's data, underscoring the urgent need for more refined information. We have further assumed that 20% of the urban population are earning sufficient income that they rely almost exclusively on energy other than that from wood fuels. The urban consumption is therefore calculated on the basis that 80% rely predominantly on charcoal, as Kabagambe (1976) has suggested.

The present population and future growth in each of the provinces and sectors that we have included are derived from the Statistical Abstracts (1977).

To derive estimates of the present and future yield of wood biomass and of the standing crop biomass, we have had to use various sources of data in the literature. There exist a number of relationships that have related both of these parameters to climatic variables. We have examined three different models which predict the yield of wood from rainfall and evapotranspiration and found that the variation amongst them is less than 40%.

The figures produced by this method only give the potential wood yield. To gain a better estimate of the actual yield and standing crop we have discounted all the land under national parks and reserves in each province, and the land under arable agriculture Table 7. We have used two scenarios to predict wood production. The high forecast assumes that all fallow land in agricultural areas produces wood fuels and that elsewhere the potential supply is achieved. The low forecast assumes that fallow land is not used for fuelwood production. It also assumes that 25% of the remaining land produces little wood fuel or has already been heavily depleted.

We have used a variety of scenarios of production and consumption to evaluate the balance of wood biomass and production at both the provincial and national level. The assumptions are given fully in the Appendix.

RESULTS

It is estimated that the present consumption of energy other than wood fuels amounted in 1975 to 1,658,000 tons oil equivalent (Singh, 1978). From our own analysis (Table 8) we estimate that the consumption of wood fuel in 1975 amounted to 4,487,000 tons oil equivalent on a low scenario and 8,447,000 on a high scenario, which amounts to 73% and 84% of the total energy consumption. Wood fuels are and will therefore, continue to be a major source of Kenya's energy supply well into the next century (Table 8).

Looked at from a national perspective (Fig. 1) the future of wood energy as an alternative to other sources does not however look promising. Based on a low consumption-high production scenario it is likely that the annual consumption will exceed annual production of wood within 25 years. Based on the low demand-low production forecast the annual yield of wood is exceeded in 1979. If we assume that the population consumes wood at the rate of our high forecast, the annual production of wood was exceeded in the early 70's based on the low production scenario, and will be exceeded in the mid 1990's on the basis of a high wood-production forecast.

These figures indicate that the sustainable supply of wood fuel has either been exceeded or will amost certainly be exceeded over the coming two decades. This need not be immediately obvious in looking at the available wood in the rural areas, largely because of the enormous standing mass of woody material that has been accumulated over the preceeding years. However, the stored mass is being rapidly depleted, whatever forecast we assume (Fig. 1). If we use the lower demand rate for wood, half of the remaining woody cover would be stripped over the coming decade; while assuming the higher demand rate, half of the remaining woody cover would be stripped over the next three decades (Fig. 1).

On a provincial basis there is a wide variation in the balance of available wood energy amongst the provinces and in the rates at which it will be consumed in the future. (Table 7). The relatively sparsely cultivated Coast and Eastern Provinces which receive a reasonably high rainfall have substantial wood reserves, while the densely populated and cultivated Central and Nyanza provinces have been consuming the standing crop of wood at a dramatic rate over the last decade. North-Eastern Province which has virtually no agricultural potential is unlikely to exceed the available wood supply in the foreseable future. However, the extent of depletion in each province will depend largely on the patterns of wood exploitation in relation to the urban and rural centres and is therefore difficult to predict in detail.

What is most obvious in the regional picture of wood supply is the role that is still played by the high rainfall areas. The amount of wood produced per annum increases with rainfall and most of the potential production is confined to the higher rainfall zones. The amount of wood production, discounted for land placed under agriculture is shown in (Table 7). Despite the amount of land already placed under agriculture in the higher rainfall zones, most of the existing production still occurs here. Even though the non-arable areas, which we have assumed to be below the 450 mm isohyte, cover some 67% of the country, they produce less than 12% of the present estimated annual production of wood fuel, (Table 6). The potential energy production per unit area is here so low that the remote arid and semi-arid areas of Kenya are unlikely to offer a significant source of wood fuel once the arable zones are overutilized.

It is also evident that the existing and planned production of fuel wood from forests is entirely inadequate to meet present and future demand. With a present annual consumption in the region of 15 million m^3 of wood per annum on our high forest (Table 4b) and a production of approximately 700,000 m^3 of fuel wood from forest reserves (Statistical Abstract 1977) the 4.7% contribution to the national level of consumption is minor. Presently only 6% of the forest area is allocated to fuel production and it is unlikely that this figure will change sufficiently in future to the extent that it will be a major source of supply.

DISCUSSION

Three factors apparently contribute substantially to the depletion of wood production and to the reduction of standing biomass. These are:

1. An increase in the population at the projected rate of 3.6% per annum.

2. A change from traditional use of fuel wood to charcoal in urban and high density agricultural areas.

3. Land demand for agricultural production.

We need to consider how sensitive the projections are to changes in the values of each of the variables of demand and supply before placing too much confidence in them. Having done so we will consider which factors contribute most to the observed trends, and how likely it is that these factors will change in time.

The consumption of wood fuel is dependent largely on the amount that is used by the subsistence agriculturalists and to a lesser extent the urban populations. The large and small scale farmers only contribute between 4.5 and 8.2% of the annual demand, so irrespective of whether one uses a high growth forecast of 6% in GNP per annum or a low forecast of 3%, the outcome changes the national quantity of wood used by a relatively small amount.

The subsistence demand is assumed as $1m^3$ on a low forecast. Some figures indicate a higher demand in the order of 1.2 to $1.3m^3$ per capita per annum (Arnold et al, 1962; IBRD, 1977). To this must be added the amount of wood used in building, which amounts to 6% (Table 5). The per capita consumption of wood in urban populations is perhaps as high as $2m^3$ per capita per annum, and with the present estimated figure of 2 million people in towns and cities, their contribution to the national use of wood may be as high as 24%. This may be expected to increase substantially over the coming two decades (Table 9) as the percentage of people in urban areas rises from the present 13% to around 25% at the turn of the century (Central Bureau of Statistics, 1972).

It is unlikely that the rate of population increase will fall substantially below its present level before the year 2000 or that the urban population will be much lower than the anticipated 6 to 8 million. The combined growth in subsistence and urban demand for wood fuels will therefore continue to grow at least as fast as the population. Given the amount of information available on per capita wood utilization, it is unlikely that there is a very large bias in the values we have adopted. We consider that the national per capita use is probably substantially higher than our lower assumption of $1m^3$ but has yet to reach the higher assumption of $2m^3$ per annum. As a larger percentage of the population come to depend on charcoal it is possible that the upper value will be reached. Although we have here assumed a conversion efficiency of 9% in producing charcoal from wood, the value may be somewhat lower since the volume of woody mass cut down but not fed into the kiln is quite substantial. In examining kilns close to Nairobi we found that most of the scrub vegetation consisting of branches and twigs less than 4 cm was discarded. This accounts for a considerable proportion of the wood chopped down for charcoal production.

The extent to which the non-subsistence sector of the population changes from wood fuel to charcoal and eventually to commercial fuels will depend largely on the growth in GNP. If we assume a rapid growth of 6% per annum in GNP then a greater proportion of the population will be in a position to purchase commercial fuels by the year 2000 and the demand for wood will therefore be somewhat lower than a low growth rate in GNP. We caution however that these assumptions are based on past relationships of purchasing power and patterns of energy consumption. The extent to which wood fuels are replaced by say fossil fuels in future will depend on price rises which cannot presently be anticipated. The faster the increases in the price of oil fuels, the greater will be the dependence on wood fuels in future.

The most uncertain component in our projections is the rate at which new land is placed under agriculture. With the present and projected growth in population, additional agricultural production will have to be brought into play simply to keep pace with the present per capita food demand. To increase the per capita food wealth will necessitate increasing agricultural production at a faster rate than population growth. While this can be achieved in part by intensifying agricultural production, a large amount will presumably be met, as is the case now, by increasing the area of land under agriculture. We have set out our assumption of the way in which the remaining arable land will be used over the coming two decades (Table 7). This is based on prevailing data and the assumption that the pattern of agricultural settlement will precede from the wettest to driest areas. Some provinces such as Nyanza have more or less used the available agricultural areas (which we assume extend to the 450mm isohyte) while others such as Coast Province offer prospects for expansion well into next century. Land that is placed under agriculture will inevitably be stripped of woody cover, though the fallow areas could produce fuel woods. Land which could be used for agriculture is unlikely to be used for fuel wood production on any scale simply because the opportunity cost is too high.

Land placed under agriculture will, according to our calculations, account for the reduction of annual wood production that is evident in Fig. 1. Its effect will be to advance the imbalance between supply and demand by approximately a decade on most of the forecasts. It will also accelerate the depletion of the standing mass of wood by close to 50%.

On the demand side we tentatively conclude that the most significant component is the demand for agricultural land, which will depress the potential wood supply by almost a half over the coming two decades, due in large part to removing, for arable farming, the land areas which make the largest contribution to the present wood production in Kenya. Land demand for agriculture will also reduce the standing mass of wood by a similar proportion, although it will also serve to fuel the increase in demand resulting from population growth. The increase in demand due to population growth will, irrespective of that due to agricultural land, depress the standing crop of wood by roughly a half over the coming two decades, but will not reduce the annual production to any large extent. The extent to which the change from subsistence to consumer economies will accelerate the use of wood could by the year 2000 exceed 30% on our most pessimistic forecast and 23% on our optimistic scenario (Table 9).

On the supply side the figures are more speculative. We consider however that the estimated production figures probably err on the high side. Data sources on total above ground production indicate that at least on a large scale in Kenya the production figures are similar to those estimated in our model (Cassady, 1973, Phillipson, 1975). The portion of total production channelled into wood mass has been derived largely from other studies and the values for a given level of rainfall are summarised in Table 7b. The only local data which we have to compare with these projected values are drawn from unpublished data in Amboseli. Here, in relatively dense bush areas, the standing mass of wood amounts to some 60% of the total biomass. Our theoretical value at the same 300mm isohyte gives 66% which is in good agreement. However, most of the climax woody vegetation has long been reduced by a combination of grazing, burning and cutting and average woody mass only contributes 10 to 15% of the biomass over much of the area.

Actual production and standing mass of wood is therefore likely to be somewhat below our theoretical computation. This is all the more likely when it is considered that extensive areas such as the Athi-Kapiti plains support little wood due to soil constraints such as waterlogging, alkalinity and salinity.

In general we consider that the patterns of surplus and deficit that we have outlined for wood fuels in Kenya indicate the main trends on a national basis. The picture we have portrayed may be more optimistic than the situation is in reality. Even so, the rate of depletion to date and the future potential for unmanaged fuel wood production looks bleak.

There are in addition various factors which will limit the extent to which the available production and standing mass of wood can be consumed. The cost of transport is particularly crucial. Earl (1975) has noted that the transport costs incurred in collecting wood fuels from natural forests in East Africa is so high that at distances greater than 80km from markets it is only profitable to carry charcoal. As local sources of fuel wood are used up around the main urban and agricultural areas it is inevitable that there will be a progressive switch to charcoal, and consequently, to a higher absolute consumption of wood per capita. Moreover, with a sharp rise in the price of oil fuels the distance within which it is profitable to transport wood will be reduced, thus further escalating the per capita consumption of wood through a switch to charcoal.

Given the large labour costs involved in making charcoal we expect that the standing mass of wood required to sustain the trade is much greater than for fuel wood. The arid areas (those below the 450mm isohyte) which are both distant from the main centres of population and which have a low wood mass will not provide much wood fuel apart from that used by pastoralists. Further constraints on use include woods that are too soft or have branches and twigs that are too small to make gathering economical. Such constraints will limit the extent to which the available wood source can be utilised as wood fuels and will lead to earlier critical shortages locally and nationally than we have predicted.

Yet a further factor which will undoubtedly limit the availability of wood supplies is the impact that its utility will have on both the environment generally and on other sectors of the economy. An accelerated reduction of vegetation cover will increase the already alarming rate of soil erosion.

The impact of an increased loss of soil can theoretically be calculated in terms of its opportunity costs on ranching, riparian agriculture, hydroelectric supplies and the productivity of marine ecosystems for example. The outcome is not a simple one to predict and would be a major project in itself. A reduction of bush cover can, for example, lead to a greater productivity of grassland pasture (Walker, 1974) and therefore of livestock. Provided the grasslands are well managed the reduction of over-all ground cover need not be great or result in a sharp increase in erosion. We consider therefore, that the optimum offtake of wood fuels should be calculated within a larger framework where the costs and benefits of reducing woody cover can be gauged relative to other sectors of the economy.

Finally, we suggest that there is an urgent need for detailed research into the field of wood fuel production in its broadest sense. For a fuel which provides over 75% of the country's total energy supply and which has the highest environmental impact, there is a distressing lack of information.

A number of effective measures can be undertaken to alleviate the future drain on wood stocks. Areas within the arable lands which are not immediately under cultivation could be used as fuel lots during fallow periods. The International Council for Research in Agroforestry is one of a number of organisations that are beginning to look at the prospects for increasing domestic fuel supplies grown in arable areas. A variety of multi-purpose trees and rotation systems offer prospects for producing a combination of livestock forage, food, shelter and firewood within the existing agricultural areas which, as we earlier pointed out, have the greatest potential for energy production (Fig. 2).

On the consumer side the most immediate gains could be achieved by increasing the efficiency of charcoal kilns and wood stoves. These aspects will be covered in detail in other papers presented at the workshop and need not be elaborated here.

REFERENCES

Arnold, J.E.M., De Backer, M.F.E. and Pringle, S.L. (1962) Report to the E.A. High Commission on present wood consumption and future requirements in Kenya.

Cassady, J.T. (1973) The effect of rainfall, soil moisture and harvest intensity on grass production on two ranges and sites in Kenya.

Chlala, H.G. (1972) The present situation and future prospects of charcoal production and consumption in Kenya. Industrial Survey and Promotion Centre, Ministry of Commerce and Industry, June, 1972.

Dyson, W.G., (1974) Experiments on growing Eucalyptus wood fuel in the semi decidous forest zone in Kenya. E.Africa.Agric.and For J.39: 349-355

Earl, D.E., (1975) Forest Energy and Economic Development. Clarendon Press, Oxford.

Economic Survey 1978. Central Bureau of Statistics, Ministry of Finance and Planning.

F.A.O. (1974) Tree planting practices in African savannahs. Rome.

Githinji, P.M. (1978) Kenya's energy needs, possible supplies and impacts on the environment. Unpublished Manuscript.

Hunting Technical Services (1976) Tigrai Rural Development Study, Annex 6, ODM.

IBRD (1977) Bura Irrigation Settlement Project Appraisal (Yellow Cover) Washington.

Kabagambe, D. (1976) Aspects of resource conservation: The role of charcoal industry in the Kenya economy. Institute for Development Studies, University of Nairobi; June, 1976.

Kenya Statistical Digest (1971) The future growth of Kenya's population and its consequences. June 1971.

Kenya Statistical Digest (1972) Population projections by district 1970-1980. September 1972.

King, K.F.S. and Chandler, M.T. (1978) The wasted lands. International Council for Research in Agroforestry, Nairobi, Kenya.

Langbein, W.B. and Schumm, S.A. (1958) Yield of sediments in relation to mean precipitation. Trans.Amer.Geophys. Union. 39: 1076-1084.

Openshaw, K. (1976) Woodfuel - A time for re-assessment. Unpublished Manuscript. Div. of Forestry, Faculty of Agriculture, Forestry and Veterinary Science. University of Dar es Salaam.

Phillipson, J. (1975) Rainfall, primary production and "carrying capacity" of Tsavo National Park (East), Kenya. E.Afri.Wildl.J.13, 171-201.

Singh (1978) Statistics of energy and power, 1969-1977. Central Bureau of Statistics, Sept. 1978.

Statistical Abstract 1977. Central Bureau of Statistics.

Uhart, E. (1975) Charcoal Development in Kenya. ECA/FAO Forest Industries Advisory Group for Africa. July, 1975.

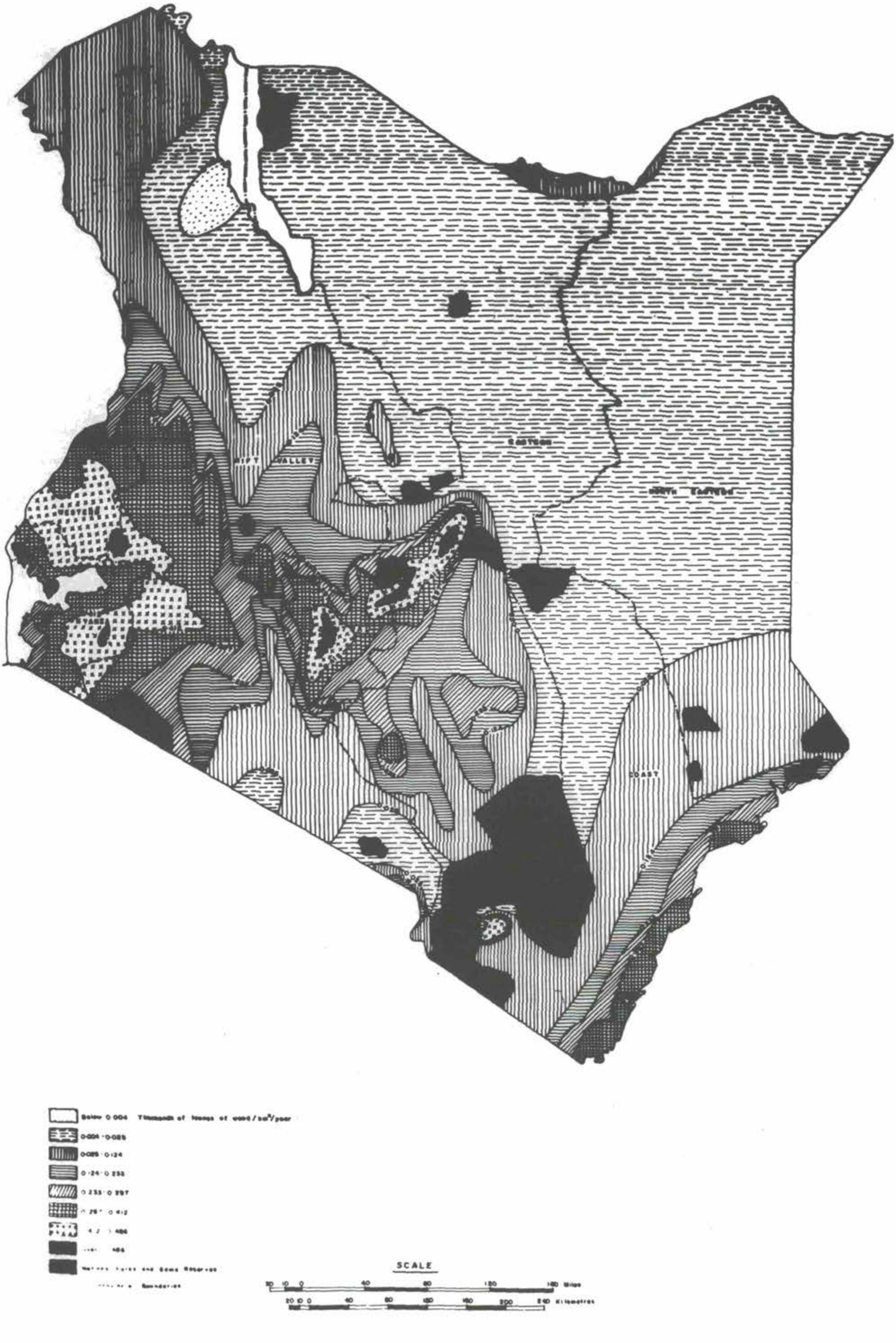
Walker, B.H. (1974) Biological considerations in the management of semi-arid ecosystems in South Central Africa; in Cave, A.J., (ed.) Proceedings of the First International Congress of Ecology: The Structure, Functioning and Management of Ecosystems. Centre for Agricultural Publishing and Documentation. Wageningen.

Whittaker, R.H. (1970) Communities and Ecosystems Collier-Macmillan Ltd. London.

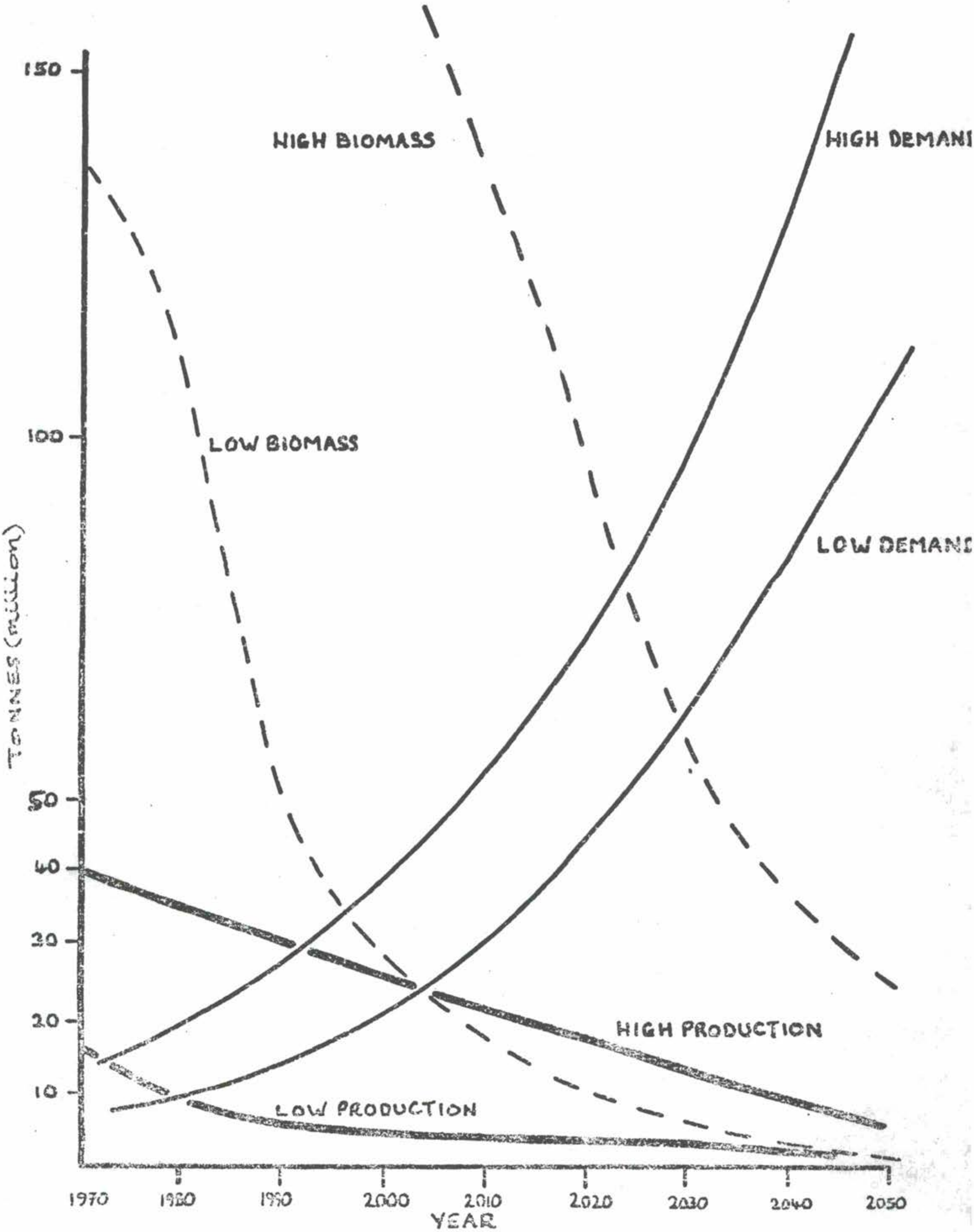
Whittaker, R.H. and Marks, P.L. (1975) Methods of assessing Terrestrial Productivity, in Leith, H. and Whittaker, R.H. (eds.) Primary Productivity of the Biosphere. Springer-Verlag, Berlin Heidelberg, New York.

FIG.1. Projections of wood demand and supply on a Kenya-wide basis. Annual demand is projected from the assumptions given in Table 3. Annual wood production and woody biomass is calculated according to the assumptions given in Table 7a.

FIG.2. Potential annual wood production calculated from the assumptions in Table 6.



RIFT VALLEY
EASTERN
NORTH EASTERN
COAST
Below 0·004 Thousands of tonnes of wood/km²/year
0·004 - 0·025
0·025 - 0·124
0·124 - 0·255
0·255 - 0·297
0·412
SCALE
20 10 0 40 80 120 160 Miles
20 10 0 40 80 120 160 200 240 Kilometres



150
100
50
40
30
20
10
TONNES (million)
HIGH BIOMASS
LOW BIOMASS
HIGH DEMANI
LOW DEMANI
HIGH PRODUCTION
LOW PRODUCTION
1970
1980
1990
2000
2010
2020
2030
2040
2050
YEAR

APPENDIX

Data sources and assumptions are given in the following tables.

TABLE 1

KENYA'S PROJECTED POPULATION BY PROVINCE IN '000

	1975	1979	1985	2000	2050*
COAST	1,158	1,333	1,669	2,969	15,436
EASTERN	2,284	2,585	3,158	5,263	19,781
N. EASTERN	264	275	290	277	238
NAIROBI	700	863	1,189	2,596	15,075**
RIFT VALLEY	2,666	3,033	3,734	6,354	35,024
NYANZA	2,645	3,076	3,914	7,231	43,524
WESTERN	1,667	1,973	2,493	4,674	29,679
TOTAL	13,413	15,427	19,310	34,288	202,871

SOURCE: Central Bureau of Statistics

The population has been projected up to 2000 using a method described in the Kenya Statistical Digest June 1971, and September 1972.

* For 2050, growth rates in 2000 have been assumed to prevail.

** Nairobi has been projected at 3.6% annual growth rate between 2000 and 2050.

TABLE 2

PER CAPITA INCOME IN 1975 US $ AND TOTAL FUELWOOD DEMAND
IN '000 TONNES ON LARGE FARMSIN PRIVATE SECTOR BY PROVINCE

		1975		1979		1985		2000		2050	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
	PER CAPITA INCOME US $	295	289	297	314	301	375	310	584	345	2559
COAST	TOTAL FUELWOOD DEMAND	3	3	3	3	4	4	4	6	36	19
	PER CAPITA INCOME	321	271	402	305	563	364	1,306	567	21582	2487
EASTERN	TOTAL FUELWOOD DEMAND	3	3	3	4	3	4	4	6	8	14
	PER CAPITA INCOME	-	-	-	-	-	-	-	-	-	-
N.EASTERN	TOTAL FUELWOOD DEMAND	-	-	-	-	-	-	-	-	-	-
	PER CAPITA INCOME	271	256	332	288	451	344	972	536	12560	2350
CENTRAL	TOTAL FUELWOOD DEMAND	17	18	18	19	20	22	26	32	61	94
	PER CAPITA INCOME	296	258	379	290	547	347	1,371	540	29370	2367
RIFT VALLEY	TOTAL FUELWOOD DEMAND	29	311	30	33	32	38	40	55	58	190
	PER CAPITA INCOME	324	294	427	331	646	395	1,821	616	57526	2701
NYANZA	TOTAL FUELWOOD DEMAND	3	3	3	3	3	4	5	6	11	25

TABLE 2 contd

		1975		1979		1985		2000		2050	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
WESTERN	PER CAPITA INCOME	226	219	285	247	541	295	969	459	17,849	2,012
	TOTAL FUELWOOD DEMAND	1	1	1	1	1	1	1	1	3	6
KENYA	$\bar{X}$ PER CAPITA INCOME	273	261	370	294	524	351	1,248	547	22,563	2,398
	TOTAL FUELWOOD DEMAND	56	59	58	63	63	73	80	116	177	348

Per Capita energy consumption:-

1. $Y = 1.84X + 125.31$ ($r^2 = .87$)

   Y = Total energy consumption (Kg CE) per capita
   X = GNP Per capita (US $)

2. % Total energy supplied by fuelwood

   $\text{Log } Y = 4.44 - 1.25 \log X$ ($r^2 = .67$)

   Y = % total energy supplied by fuelwood
   X = GNP per capita (US $)

   Source for Equations Earl (1975)

Total fuelwood use was calculated by finding the per capita fuelwood demand using equations (1) & (2), originally as Kg CE then converted to wood equivalent. This was multiplied by the number of people projected to be employed on the large farms. The projections were based on data published by the Central Bureau of Statistics.

Per Capita income was projected on 2 scenario, high and low which use an observed national annual growth rate of 6.06% Central Bureau of Statistics (1973 - 1978) and an assumed growth rate of 3% respectively.

TABLE 3

PER CAPITA INCOME IN 1975 PRICES US $ AND TOTAL FUELWOOD DEMAND IN '000 TONNES ON SMALL FARMS BY PROVINCE

		1975		1979		1985		2000		2050	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
COAST	PER CAPITA INCOME	109	109	168	122	323	146	1,651	227	381,541	997
	TOTAL FUELWOOD DEMAND	75	75	68	82	61	90	58	119	78	377
EASTERN	PER CAPITA INCOME	106	106	122	120	151	143	255	223	1,456	976
	TOTAL FUELWOOD DEMAND	151	151	154	156	162	167	192	204	434	490
N. EASTERN	PER CAPITA INCOME	-	-	-	-	-	-	-	-	-	-
	TOTAL FUELWOOD DEMAND	-	-	-	-	-	-	-	-	-	-
CENTRAL	PER CAPITA INCOME	116	116	111	130	105	155	91	242	56	1,060
	TOTAL FUELWOOD DEMAND	126	126	150	136	187	150	335	194	1,352	563
RIFT VALLEY	PER CAPITA INCOME	128	128	153	144	200	172	392	267	3,696	1,172
	TOTAL FUELWOOD DEMAND	156	156	165	173	177	190	218	255	590	821
NYANZA	PER CAPITA INCOME	124	124	194	140	378	167	2,002	260	519,728	1,142
	TOTAL FUELWOOD DEMAND	158	158	145	168	128	196	134	274	211	1,022
WESTERN	PER CAPITA INCOME	75	75	72	84	67	101	57	157	33	688
	TOTAL FUELWOOD DEMAND	112	112	128	139	156	168	255	228	1,408	1,438
KENYA	PER CAPITA INCOME	105	105	126	118	167	141	335	220	3,430	963
	TOTAL FUELWOOD DEMAND	779	779	809	855	870	961	1,192	1,103	4,072	4,711

The same method as on large farms was used except that per capita income was projected at a 4.7% high scenario based on data published in the Statistical Abstract (1977) and an assumed growth rate of 3% on the low scenario.

TABLE 4(a)

TOTAL FUELWOOD DEMAND FOR THE SUBSISTENCE AND URBAN POPULATION IN '000 TONNES

PROVINCE	1975		1979		1985		2000		2050	
	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
COAST	730	1,460	840	1,680	1,055	2,111	1,895	3,791	9,728	19,457
EASTERN	1,446	2,892	1,642	3,284	2,015	4,031	3,401	6,801	12,529	25,058
N. EASTERN	396	198	412	206	436	218	416	208	358	179
NAIROBI	504	832	621	1,025	856	1,413	1,869	3,084	10,854	17,909
CENTRAL	1,245	2,490	1,420	2,840	1,760	3,521	3,059	6,117	14,264	28,527
RIFT VALLEY	1,614	3,228	1,828	3,656	2,252	4,505	3,846	7,692	21,206	42,411
NYANZA	1,677	3,354	1,950	3,900	2,489	4,977	4,640	9,279	27,596	55,193
WESTERN	1,061	2,123	1,239	2,478	1,591	3,182	3,010	6,020	18,889	37,778
KENYA	8,673	16,577	9,952	19,069	12,454	23,958	22,135	42,992	115,424	226,512

Subsistence per capita fuelwood demand is derived from Table 5, which gives $1m^3$ per capita per annum. For the high demand scenario this figure is doubled to $2m^3$ annual per capita demand.

The per capita demand is then multiplied by the number of people in a province from Table 1 after discounting for those employed on large and small farms.

For the urban population per capita demand is taken from Chalala (1972) and Kabagambe (1976). Here 100Kg and 165Kg charcoal per annum are used, for the low and high demand respectively.

TABLE 4(b)

TOTAL FUELWOOD DEMAND BY PROVINCE IN '000 TONNES OF WOOD

(INCLUDES FUELWOOD DEMAND ON LARGE FARMS AND SMALL FARMS AND SUBSISTENCE AND URBAN)

	1975		1979		1985		2000		2050	
PROVINCE	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
COAST	807	1,538	911	1,765	1,120	2,205	1,957	3,916	9,842	19,853
EASTERN	1,646	3,046	1,799	3,444	2,180	4,202	3,597	7,011	12,971	25,562
N. EASTERN	198	396	206	412	218	436	208	416	179	358
NAIROBI	504	832	621	1,025	856	1,413	1,869	3,084	10,854	17,909
CENTRAL	1,388	2,634	1,588	2,995	1,967	3,693	3,420	6,343	15,677	29,184
RIFT VALLEY	1,799	3,351	2,023	3,862	2,461	4,733	4,104	8,002	21,854	43,422
NYANZA	1,838	3,515	2,098	4,071	2,620	5,177	4,779	9,559	27,818	56,240
WESTERN	1,174	2,236	1,368	2,618	1,748	2,351	3,266	6,249	20,300	39,222
KENYA	9,355	17,613	10,613	20,193	13,169	25,210	23,200	44,419	119,493	231,750

This is the sum of Tables 2, 3, and 4(a)

TABLE 5

DATA SOURCES FOR SUBSISTENCE WOOD DEMAND

	m^3/capita/annum
IBRD TUNISIA/KENYA 1977	1.238
EAAFRO(DYSON 1974) (HIGHLANDS)	1.122
ARNOLD et al (1962)	1.027
FAO (1974)	0.980
HUNTING TECHNICAL SERVICES (1976)	0.619
$\overline{X}$ =	0.997 ± S.D.0.23 SE ± 0.10

OF THIS CONSUMPTION % USED AS FUELWOOD:-

	BUILDING	FUEL
IBRD (1977)	2%	98%
FAO (1974)	8%	92%
HUNTING TECHNICAL SERVICES (1976)	8%	92% (98% as fuelwood)
		$\overline{X}$ = 94% ± SE 173

TABLE 6

% OF POTENTIAL ANNUAL WOOD PRODUCTION BY RAINFALL ZONE AND PROVINCE

MEAN ANNUAL RAINFALL(mm)	POTENTIAL WOOD PRODUCTION IN 000 TONNE/Km^2	COAST	EASTERN	N. EASTERN	CENTRAL	RIFT VALLEY	NYANZA	WESTERN	KENYA	ANNUAL WOOD PRODUCTION 000 TONNE FOR EACH ZONE
200	0.004					0.1			0.03	13
250	0.006					0.4			0.2	76
300	0.010	0.5	9.3	46.8					3.6	1,804
350	0.016			18.8		2.2			1.6	786
400	0.025	5.1	1.5			1.0			1.4	707
450	0.032	8.7	1.6	25.8		6.4			5.0	2,526
550	0.099	14.7	13.1	8.6		7.3			7.8	3,944
600	0.124		0.4						0.1	40
650	0.149	9.3	13.1			8.8			7.4	3,707
750	0.199	13.7	14.1		3.2	10.3			9.0	4,521
800	0.233		6.7						1.3	652
900	0.272	20.8	13.0		18.8	15.9			13.2	6,636
1000	0.297	19.6					12.9	1.9	4.0	2,019
1100	0.359		6.0		10.3	12.4	20.1	12.4	9.6	4,826
1200	0.375	7.6			1.2	8.2			4.4	2,220
1300	0.396		12.0		26.9	15.7	21.9	24.3	14.2	7,144

TABLE 6 cont'd

MEAN ANNUAL RAINFALL (mm)	POTENTIAL WOOD PRODUCTION IN 000 TONNE/Km^2	COAST	EASTERN	N. EASTERN	CENTRAL	RIFT VALLEY	NYANZA	WESTERN	KENYA	ANNUAL WOOD PRODUCTION 000 TONNE FOR EACH Z
1400	0.412					2.4			1.0	494
1500	0.421				13.4	5.9	31.0	25.3	7.8	3,940
1600	0.434		5.7			2.6		29.9	4.0	2,014
1800	0.470				17.0		12.4		2.4	1,222
2000	0.486		3.4		9.3	0.5	1.7	6.2	2.1	1,049

Potential annual wood production was predicted using Whittaker(1970) giving the relationship between net above ground primary production and mean annual rainfall. This was then used to predict annual wood production from Whittaker and Marks (1975) who give the relationship between net above ground primary production and annual estimated increase in volume. This was then converted to weight using density of wood; $1m^3$ = 750 Kg wood (Earl, 1975).

TABLE 7(a) POTENTIAL ANNUAL WOOD PRODUCTION BY PROVINCE IN '000 TONNES AND WOODY BIOMASS IN '000 TONNES

		1970		1979		1985		2000		2050	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
COAST	WOOD PRODUCTION	2,045	6,097	1,424	5,848	1,020	5,591	336	4,682	-	760
	WOODY BIOMASS	22,202	61,913	16,787	58,357	9,986	54,699	4,337	42,712	-	8,083
EASTERN	WOOD PRODUCTION	1,942	7,566	1,289	6,990	1,110	6,561	-	5,127	-	900
	WOODY BIOMASS	17,487	71,495	10,908	63,136	8,707	55,114	-	43,365	-	9,003
N.EASTERN	WOOD PRODUCTION	1,689	1,689	1,689	1,689	1,689	1,689	1,689	1,689	1,689	1,689
	WOODY BIOMASS	17,585	17,585	17,585	17,585	17,585	17,585	17,585	17,585	17,585	17,585
CENTRAL	WOOD PRODUCTION	163	2,031	-	1,740	-	1,028	-	-	-	-
	WOODY BIOMASS	2,191	33,449	-	21,428	-	12,316	-	-	-	-
RIFT VALLEY	WOOD PRODUCTION	8,107	18,027	6,393	17,340	5,060	16,717	4,142	14,405	358	1,873
	WOODY BIOMASS	95,694	241,151	85,116	224,911	51,231	211,153	24,752	160,237	4,749	20,095
NYANZA	WOOD PRODUCTION	36	3,543	-	3,030	-	2,548	-	864	-	-
	WOODY BIOMASS	677	76,562	-	60,517	-	45,788	-	12,663	-	-
WESTERN	WOOD PRODUCTION	21	2,185	-	1,803	-	1,446	-	125	-	-
	WOODY BIOMASS	478	55,484	-	42,639	-	31,487	-	1,872	-	-
KENYA	WOOD PRODUCTION	12,314	41,138	9,106	38,440	7,190	35,580	4,478	25,892	2,047	5,222
	WOODY BIOMASS	156,314	557,639	130,396	448,573	87,509	428,142	46,674	278,434	22,334	54,766

TABLE 7(a) contd

Low Production = Table 6 data X (AREA - TOTAL AGRICULTURAL LAND) X 0.75

High Production = Table 6 data X (AREA - TOTAL AGRICULTURAL LAND - AGRICULTURAL FALLOW).

Agricultural land projected from data published in the Statistical Abstract, 1977.

Biomass is predicted from Langbein and Schumm (1958) and is reduced by a given % to get the word biomass (Table 7b)

Agricultural land has been projected as the sum of large and small farms. Large farms are projected on a compound growth rate using data in the Statistical Abstract (1977); while small farms are projected using a per capita agricultural land demand of 0.003 Km^2; Physical Planning Department (1978) Human Settlements in Kenya: A Strategy for Urban and Rural Development.

TABLE 7(b)

ANNUAL RAINFALL (mm)	% BIOMASS THAT IS WOOD
200	50
250	55
300	66
400	70
450	72
500	76
550	80
600	84
650	86
700	88
750	90
800	92
850	94
900	95
1000	97
1100	99
1200	100

Log Biomass (g/m^2) = 2.72 log Annual Rainfall (mm) - 1.8
AND DATA SOURCES IN TABLE 7 (a)

TABLE 8

COMMERCIAL ENERGY CONSUMPTION

	1975	1979	1985	200	2050
'000 TONNES OIL GDP-HIGH (6%)	1,658	2,237	3,391	8,810	171,115
GDP-LOW (3%)	1,658	1,940	2,399	4,042	19,425
DIRECT PROJ. 6.9%	1,643	2,144	3,197	8,676	241,922
TOTAL WOOD DEMAND AS '000 TONNE OIL HIGH	8,447	9,684	12,091	21,303	111,145
% TOTAL	84	81	78	71	39
LOW	4,487	4,888	6,316	11,127	57,308
% TOTAL	73	72	72	73	75

SOURCE: Singh (1978)

The projections have been made using an equation derived from data by Singh (1978) giving the relationship between total GDP and total energy consumption of Kenya and total GDP vs per capita Kg of oil equivalent consumption.

$Y = 1.3273X - 34.018$ ($r^2 = 0.99$)
Y = total energy consumption in '000 tonnes oil equivalent.
X = GDP in K£

The equation uses indices where 1972 = 100 for both GDP And energy consumption.
Fuelwood was converted to oil equivalent on a heat basis using conversion factors in Earl, (1975).
GDP was projected at annual growth rates of 6% (high) and 3% (low)
Direct projections of oil consumption were also made for comparison.

FINDINGS OF THE WORKSHOP

ESSAM EL-HINNAWI
United Nations Environment Programme

Several important issued emerged during the discussions of the papers presented at the Workshop and during the round table discussions of th e Working Groups. These issues deal essentially with questions of development, technology transfer, energy policies, supply/demand in rural and urban areas, and conservation measures.

The findings of the Workshop are summarized in the following:

(1) Developing countries should be helped to follow a path to development suited to their technical skills, to their natural resources and to their social and cultural circumstances.

(2) The fulfilment of basic human requirements, especially those of the poorest strata of the population (focussing on food, shelter, health and basic education) is undoubtedly, a central indicator and measure of development.

(3) Developing countries should have access to the technologies that they require for their own development. These technologies should be capable of adaptation to their own conditions (socio-economic and environmental), and should not be thrust upon them, which might detract from the success of development and prejudice its output.

(4) National energy policies should be formulated on the basis of the following three main elements:

(a) Energy conservation, through (i) increased efficiency of production and use of energy, (ii) rational (non-wasteful) use of energy.

(b) Development of an alternative "mix" of energy sources.

(c) Environmental soundness

(5) In formulating energy policies in the developing countries, both the commercial and non-commercial sources of energy must be taken into account. The latter sources constitute more than 70% of the energy consumed in many rural areas of the developing countries.

(6) Appropriate energy sources must be developed to promote rural development. In this respect concentration should be made on the development of locally available renewable sources of energy.

(7) It is appreciated that in the short-and medium-terms, fuel wood will continue to be the main source of energy in rural areas of

East Africa. Research and developme nt should, therefore, be accelerated to use wood and charcoal more efficiently. Parallel to this, efforts should be made to increase public awareness about appropriate forest management and afforestation and to accelerate the harnessing of other locally available renewable sources of energy with the target of achieving an economically, socially and environmentally-sound energy "mix" suitable for achieving sustainable rural development. In this respect, focus should be made on small hydro-power schemes, biogas, solar energy, geothermal energy, wind power and other suitable sources.

(8) It is important to set up a national energy research and development programme for rural areas which should focus on transfer and adaptation of appropriate energy technologies.

(9) In the urban and industrial sectors, energy conservation must be promoted through the introduction of technological innovations to increase the effeciency of production and use of energy and through the rational non-wasteful use of energy. This should be supplemented by adequate legistations and increasing the public awareness about conservation measures.

(10) To achieve the preceding strategies and policies, a national data base should be established to provide adequate and accurate infor mation on energy supply/demand in the different sectors of the economy and most important in rural areas. This data base will make it possible to formulate adequate scenarios of the energy needs of the country, which might vary by time according to national discoveries, development strategies and/or regional or global geopolitical situations.

ANNEX I

OPENING ADDRESS

by

MINISTER FOR ECONOMIC PLANNING AND COMMUNITY AFFAIRS
HON. DR. ROBERT OUKO, M.P.

Mr. Chairman, Distinguished Scientists, Ladies and Gentlemen; I feel honoured to have this great opportunity to welcome you all to this Workshop and to open yet another forum on energy whose object is to some extent complementary to the one I opened in late November 1978 entitled "Coping with Energy Crunch in a Growing Kenya" and which had been organised by the National Council for Science and Technology.

As we all know, a lot has been said all over the world about the diminishing conventional energy commodities and the possibilities of introducing non-conventional energies as substitutes to meet the ever growing demand for energy. The most widely discussed energy commodity is oil, whose price has been increasing unabated since the 1973/74 oil crisis which was sparked off by the Middle East War. Possibilities of developing technologies which are more energy efficient while at the same time are economically competitive with existing ones have also featured dominantly in many national, regional and international conferences, seminars, workshops and symposia.

The developing countries which are net importers of energy and of which Kenya is one, are the most affected by the escalation of prices of petroleum products since they have to spend considerable amount of their foreign exchange earnings to import their oil requirements. The escalation of prices of petroleum products has had chain reactions in many industries all over the world which depend on petroleum products for their production processes with the resultant effects of galloping inflationary setting. The world wide inflation has had many casualties in nearly all the developing countries as they depend on imported plant and machinery and in some cases raw materials for their economies. As a result of these attendant economic pit falls, many countries are experiencing persistent balance of payment problems to the extent that they are almost finding it impossible to meet their import requirements even with external economic assistance. We in Kenya are also not find it easy going as 85% of our commercially traded energy is derived from imported oil and we have to spend close to 25% of our foreign exchange earnings to import our oil requirements.

There is an acute shortage of energy in Kenya and especially in the rural areas. And one of the toughest challenges that we in charge of socio-economic planning for this country's development are faced with is how to provide the rural population with adequate energy to meet most of their energy requirements for essential activities such as cooking, lighting, etc. while at the same time providing adequate domestic and commercial energy to meed demand for the modern sector of our economy. Parallel to this challenge, is the fact that the theme of the Kenyan Fourth Development Plan 1979-1983, which is the alleviation of poverty cannot be approached and redressed in isolation of the eminent rural energy crisis. Furthermore, it is needless to say that alleviation of poverty and increased consumption of energy per capita have been known to have some correlation.

Turning to the development of energy and other related projects during the IV Development Plan, the following programmes will be carried out:

Development expenditure in the electricity sector will be organised in four main programmes:

(i) Generation

(ii) Transmission and Distribution

(iii) Rural Electrification

(iv) Geothermal

The generation and transmission programme will require investment in excess of K£98 million (excluding the upper reservoir of Tana River). Reinforcement and extension to sub-transmission and distribution lines will require an investment of a further K£ 15.63 million. Domestic installed generating capacity will rise from 320 MW in 1977 to 535 MW in 1983. Based on current price level, a sum of K£ 71 million will be spent on additional generation plant during the plan period. This figure excludes the capital cost of the Upper Tana River Reservoir which is approximately K£ 50 million and which is being funded as a multi purpose project.

The total expenditure during the plan period for transmission and distribution will be about K£ 44 million including K£ 27 million for transmission.

The Rural Electrification programme will cost K£ 4.7 million during the plan period. This figure is four times more than the amount allocated for the rural electrification programme in the III Development Plan Period, 1974-1978.

During the Plan Period further expenditure on geothermal potential of the country will be carried out in the areas in the Rift Valley Province other than Olkaria. The funds required for further exploration will be in the neighbourhood of K£ 2 million. Exploitation of the existing potential will include construction of one 15 MW station at Olkaria which is planned for completion in 1981 at a cost of K£ 12 million, followed by another 15 MW station in the following year at an additional cost of K£ 8 million. The total geothermal potential is estimated at between 170-500 MW.

As far as other sources of energy are concerned wood and charcoal are the main sources of energy in the rural areas where more than 80% of our population live. Charcoal and wood consumption is provisionally estimated to be well in excess of 10 million tonnes per annum. Most of the fuel wood is obtained from private woodlots with the Forest Department only providing a small quantity of the total national demand. Over 70% of the planned development expenditure of the K£ 42 million allocated for the Forest Department will be spent on the development and maintenance of forest plantations over the Plan period. However, for conservation of soil and water resources, priority attention will be accorded towards rural and local afforestation of the arid and semi-arid areas. To this end the following measures will be fostered and accelerated :

(1) Marginal land forest research in tree seedlings which can grow under semi-arid and arid conditions will be carried out. Thus the plant species to be bred and developed should be able to grow and mature quite fast with very little water, much of which is saline. During the Plan period the Government will spend K£ 376,000 on marginal land forest research. This is a very small sum of money indeed when one considers that about 80% of our land is in the category of low potential - i.e. semi arid and arid. Due to other pressing national requirements all of which are competing heavily for funding the Government was not able to allocate a bigger sum for the marginal land research. It is however my belief that depending on the amount of effort the scientists both in government and at the University put in the marginal land research a lot can be achieved to justify consideration for allocation of more funds.

(2) The public will be made to appreciate the importance of planting and growing more trees on their holdings through tree planting campaigns in form of barazas organised by Provincial Administration. For the campaign to be more effective at the grass root level people will be provided with seedlings on a continuous basis. Each location will in the near future have a tree nursery under the auspices of the chief's office. The seedlings from these nurseries will be provided to the people at highly subsidised prices.

(3) Since wood and charcoal are the main sources of energy for the rural areas, possibility of making charcoal briquettes from saw dust, coffee husks, wood shavings and other vegetable wastes will be carried out to supplement fuel wood. Already, some prefeasibility studies on this project are being carried out by several quasi-government and government organisations i.e. Kenya Industrial Estate, Industrial Survey and Promotion Centre of the Ministry of Commerce and Industry, the Industrial Development Bank and Kenya Planters Cooperative Union.

What is required of you scientists, if I may so say, is for you to come out with appropriate techniques which are both efficient and cost effective. For example, we expect you to design and develop technologies which are cheap and which will optimise the charcoal output from the feed-stocks. In addition to this, there are yet two other major issues which are of technical nature and for which no appropriate solutions have been found. These are the low efficiency of the traditional pit kilns for manufacture of charcoal and the traditional charcoal stove whose effective heat output is rated at between 15 - 20%. Here again I call upon you scientists to come out with cheap but better designs of these two technologies. While tackling these issues you will have to bear in mind the role played by the informal sector in the manufacture of the charcoal stoves and in charcoal making - that is, if new technologies are to have any social impact they must be competitive in prices with the already existing ones.

There is potential for solar, biogas and wind energies in Kenya but little research and development work has been done to assess their impact on alleviation of our national energy problems. At the moment there are scattered unplanned and uncoordinated small scale uses of windmills for pumping water and biogas for cooking, lighting, etc. and wide spread use of solar energy for drying purposes. Solar energy is also used for domestic and commercial water heating in small scale.

High capital costs of rural electrification (which at the moment costs at least shs.20,000/- per kilowatt) in general and in particular in the sparsely populated semi and arid areas - coupled with high electricity tarrifs which are not within the financial capability of the majority of rural households calls for diversification of energy sources. To this end, research aimed at harnessing solar, wind and biogas energies cheaply to meet the daily basic needs (such as cooking, lighting, etc) of the rural polulace would be most welcome at this stage of our socio-economic and cultural development. The Government would certainly not hesitate to provide assistance that may be required for carrying our research and development work aimed at alleviating our energy problems. The National Council for Science and Technology which comes directly under my ministerial responsibility has set up a small research fund to start with and depending on how this fund is going to be utilised to enhance the quality of life of our society, I can assure you that more research funds will be provided. Scientists will be expected to bid for research support from the fund but only submissions which have relevance will be given special attention.

Before I turn on to institutional arrangements, I would also like to say that there are other areas of socio-economic development which require considerable amount of energy and which I hope will also receive some attention from this workshop. Such one area is irrigated agriculture of arid and semi arid area which requires a lot of energy, for example, for drilling bore holes and desalination of water so that it can be used for both human consumption and crop growing; this is but one example.

On the question of institutional issues, the exploration and development of energy resources has been the responsibility of a number of Ministries. However, a number of problems which had not been foreseen have over the years cropped up; these are:-

(i) The problem concerning explicit policy on energy development has necessitated the formation of Committee on Energy Policy and Resources under the ambit of the National Council for Science and Technology whose task has been to formulate a coherent energy policy for Kenya. Arising out of the Committee's recommendation a Department of Energy has been set up under the Ministry of Power and Communications to handle matters relating to energy development and utilization.

(ii) The problem concerning lack of national institutions to carry out research and development work in the field of energy and which should be examined with a view to making concrete proposals for setting up energy research institution.

(iii) The problem concerning lack of specific energy financing in institutions to foster the development of new energy technologies and resources has been identified and the NCST Committee on Energy Policy and Resources should make suitable recommendation of how this problem can be tackled.

Mr. Chairman, I would like to wind up my address by requesting the workshop to critically analyse the issues that I have enumerated and to give them a wider dimension by diversifying the approach to energy problems with a view to providing solutions which are within financial management of a developing country like Kenya. With these remarks, I declare the workshop opened.

Thank you.

Dr. Robert Ouko

ANNEX II

KEYNOTE ADDRESS

PETER GACII
SECRETARY KENYA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Just a few months ago I was privileged to open the National Symposium organised by the NCST. Its objective was to help the Government to formulate a comprehensive energy policy. Since then we have had several workshops and seminars dealing with one aspect or another of the energy problems facing us and now we are together again to spend the next few days on discussing energy. I have been asked the question - and indeed I myself pondered it - is this a healthy process? Is it not an overkill? Is there anything new to contribute, or are we saying the same things over and over again?

Obviously there is a need to be selective about these exercises. But before one can really judge this question the reason for the high level of interest must be examined. It is much too simplistic to say that the events of 73/74, and again those of the past few months, have driven home the point that energy is vital for survival and the whole world seems to be much too exposed to uncontrollable events taking place in a few countries which can cause worldwide catastrophies. While this is no doubt the truth, it is not the whole truth. We are not only experiencing an - in part - politically motivated and artificially created supply crisis in a vital commodity, but this coincides with the dawning of totally new consumption patterns associated with the development of the Third World. We must, therefore, examine several aspects of this question.

First of all an overview of available supply of commercial energy and also access to this supply is needed. Dwelling for a moment on this first question, it is quite evident that there is no consensus on either of these two aspects. Many feel that there is no real shortage in commercial energy commodities and by the time the existing commodities are exhausted, the human mind will find substitutes. Others are of the view that real rather than artificially created shortages will develop very soon, and that it is no good to lay our trust in as yet unknown future technologies as we may not be always so lucky as we had been in the past and the problem may outgrow our ability to cope with in time.

Both of these schools of thought agree, though, that whether or not we will be faced with serious physical energy shortages in a hundred years we do have considerable problems in the next few years which relate to universal access to energy. Some of us have been aware of it for quite some time, others have joined the club more recently, but in spite of this growing recognition no real solution is as yet on hand.

Second, there is a more or less universal agreement that the basic energy commodity of probably more than half the world's population is wood and to a lesser extent agricultural waste. There is little disagreement that the poorest of the world's populations, those that have the farthest to go before their access to commercial energy can be assured, are facing gigantic problems whose solution requires a unified effort of both the industrialized and the developing countries.

Moreover, both quantitative and qualitative changes in energy consumption pattern have a critical impact on our ecology and increased consumption tends to change our environment for the worse. This aspect, I believe, is one of the focal points of the present seminar.

Having said this much, I feel the question posed earlier, are we not over killing the subject of energy is really answered to a large extent. We must keep searching for answers until we find them, but we must organise our effort so that we aim at solutions rather than repeating ourselves.

Let me tell you very briefly what was the background to the National Energy Symposium held at the end of last year and how this present effort can link up with it.

When we decided to organise the National Energy Symposium we felt that there was a great deal of knowledge and ideas about many aspects of the energy problems in this country, but there was no forum to communicate with one another. We wanted to find out how people in the different areas of business, academic and government activities associated in some way with energy felt about our problems. We also wanted to survey technologies and their applicability to Kenya and define the major gaps in policy and institutional infrastructure necessary for the formulation and implementation of appropriate policies. Furthermore we set out to gather the views of the informed public and opinion makers on the rough order of priorities and the kind of strategies or programmes needed to meet them.

I believe we succeeded in attaining these objectives. The Committee on Energy Policy and Resources has recently received and is still considering the report on the Symposium and its findings. It appears that we may follow a three phased approach to the formulation of a national energy policy. The first one was the Symposium and the analysis included in the aforementioned report. I think this provides us with a basic conceptual framework on the views of a wide variety of personalities in business, academia and government. It defines the important questions to be answered and sketches the parameters of programmes needed. This more or less also gives us a rough priority ranking in our future activities.

The second phase of the policy formulation process will take under individual scrutiny the various alternatives, assemble them into what one may call policy packages, analyse their relative merits and disadvantages and determine their financial and economic costs in the context of the national development plan, and finally in the third phase we will develop actual programmes (projects) and strategies (guidelines and fiscal measures) necessary to implement these policy packages.

It is in these latter phases, which we are going to tackle in the next few months, that this present seminar can help us most. The National Energy Symposium had received a number of sophisticated scientific papers, but its major objective - as I have outlined above was one of scooping different views of a wide variety of people rather than getting into the complex technical details. To design concrete projects and to assess the resource requirements of these, one needs, however, a closer knowledge of the technology its costs and applicability and investigate the impact on the human environment. Judging by your programme in this seminar you set out to accomplish exactly this.

A great deal of your deliberation will focus on detailed assessmen ts of energy demand and supply for both the urban and the rural sectors of our economy. We need this and we will want to reconcile any differences between the results coming out of our own studies - we have one for each sector of the economy - and those resulting from this seminar.

There are several major issues which are encumbering the policy formulation process in most developing countries including Kenya. Let me mention some that, I hope this workshop will address and perhaps generate useful ideas towards solving them.

Can rural electrification make a real inroad in the rural energy picture, and if yes, how? We are, as you all know, involved in a rural electrification programme, but we must admit that the scale and scope of these projects is limited. Can we make a major impact on the rural energy for small scale hydro? Is it essential to link it with small scale industrial activity as some experts seem to believe? Or can it be viable by serving purely domestic consumption needs?

I see in the programme that you have an interesting item relating to biomass. We are all very enthusiastic about this subject. We feel that it is the most promising technology for supplying the rural population with energy. There seem to be however, at least four major problems. First of all there is some difficulty regarding the s ystem's reliability. I don't believe though that these are insurmountable nor do I feel the present capital costs - which are a serious obstacle - cannot be substantially reduced. The Chinese and the Indians have made great leaps forward in this respect. The more difficult problems seem to be associated with the social acceptability and the sheer task of managing such a programme on a growing scale. Gaining knowledge and advice in these areas would be of great value, indeed.

The Daily Nation of Friday April 20th, Sunday 22nd, and Friday 27th 1979 carried interesting articles which explained how a group of slum boys in Nairobi have been proving the efficiency and practicability of biogas for the last two years. They stumbled on the gas accidentally and since then have dubbed it "The fire of God". Their discovery came when they were roasting maize on a piece of ground that has been used as a garbage dump for some years. They saw flames spring suddenly from the ground next to where they had lit their own fire. The boys were at first very perplexed but later they reconciled themselves to the fact that the new fire which showed no signs of dying out or spreading, was a gift of God and should be accordingly made use of. They constructed a fire stove by placing an old open 44 gallon oil drum over the exit hole and have for more than two years been using this fire which never goes out for all their heating requirements including cooking and keeping themselves warm at nights. These boys' experience is not an experiment but is an accidental discovery which is more than demonstrating the immense potential of using renewable biogass for providing ene rgy to the public.

You will also be discussing the future of solar energy in this part of the world. This is a delicate subject people often tend to approach either in a somewhat simplistic way by discovering that there is a lot of sunshine in the tropics and we should make great use of it by harnessing its powers, or they sometimes get bogged down in the scientific intricacies of the various methods of this harnessing process. While scientific research and deliberations of its details is useful and essential within the scientific or expert community, to the kind of audience we would like to reach which includes the policy-makers - it will be imperative to find out what can and what cannot be done nor or in the near future and the conditions necessary for these developments. It became clear in the National Energy Symposium that inspite of the tremendous promise solar energy holds there are still considerable gaps inhibiting practical use. However, it is equally clear that it can be already applied in some - albeit limited areas and that we are on the threshold of important breakthroughs. Again, this workshop could contribute significantly by clarifying the applications which are adequately developed to become concrete projects and by reviewing the state of the art to provide guidance for our researchers, where to concentrate their input in order to avoid duplications and to get - so to say - the biggest bang for their effort.

It is one of the most important conclusions of the National Energy Symposium that there are no miracle solutions at hand to solve the real energy problems and that for some considerable time to come our population, at least the vast majority of it, will have to rely on firewood for its energy supplies. It seems equally clear that if a major catastrophy is to be avoided we must develop policies, based on viable technologies to achieve an appropriate blend between the introduction of new forms of energy on an ever-growing scale and to embark on a major reforestation and wood supply management exercise. This workshop could help us with the choice and method of introducing these new forms of energy as well as with advice on the necessary reforestation programmes and the technical prerequisites for it. Obviously a lot more has to be done than simply saying that we must plant trees and we must stop cutting them indiscriminately. Another example of myopic attitude is the somewhat strange advice that tends to come up from time to time, that we should refrain from introducing to our rural masses such living habits in general and eating customs in particular which are energy intensive. As one example people refer to the spread of cooked maize as a staple diet in certain parts of the country which had not followed the practice of cooked food before and which resulted in a drastic loss of vegetation cover which was used up for cooking food. No doubt development requires energy, but should we forsake development because energy is scarce? I don't believe we have come to this yet. Solutions to our societal and development problems must be mindful of their energy implications but not taken up a defeatist approach.

I hope that your deliberations on the wood/charcoal problems will give us help in trying to cope with this most difficult issue. Moreover I feel that when our recently completed rural energy survey is released the sheer magnitude of the problem will become evident and so awesome that this will mobilise all available resources. I should mention here that in my opinion, past estimates grossly under-stated the country's firewood needs and consequently the difficulty facing us is much bigger than previously estimated.

There is yet another issue I'd like to draw to your attention. This relates to the lack of firm facts and figures affecting many of our energy problems. This presents a particularly difficult dilemma as without having this information how can we find fitting solutions? Yet many aspects of our new energy policies may have to be decided upon in the absence of accurate information as they may not be available in time. We must of course recognise that what information is really needed is to protect us against making wrong decisions, in other words to eliminate risks. Well, to some degree this is a very reasonable precaution both in terms of the harmful consequences wrong decisions can have on ultimately not finding the right solution and also in the wastage of scarce resources. But we must also recognize that many of the problems facing us are very urgent and when looking at this issue in a total context one often finds that taking no risks is the greatest of all risks. The reason why I am saying all this is because I wish to drive home the point that in my judgement time is running out and we will have to make hard choices first of all affecting our rural energy systems, but also that of the modern sector. We must make these decisions with the help of the best information available, but we cannot retreat into the never land of "on the one hand this, on the other hand, however.......". So we expect that this workshop will give us as much and as accurate information as possible, but when and where there are gaps in information or data your deliberations will help us in making the right decisions by using your expert opinions.

I believe, my message is quite clear. We welcome all the clarifications and answers - even if they are not the final ones - you can give us. If all the expertise this group possesses is properly harnessed it will make the final decisions better. It requires though a coordinated effort between the technical experts and the policy makers. The technical experts must understand the needs of the policy makers who in turn have to appreciate the extent to which the technical advice given is based on judgement and assumptions rather than undisputable facts.

Before I conclude there is one more point that should be raised. The title of this workshop is Energy and Environment in East Africa. In the developing world it is not possible to talk about either of these subjects without linking them to social and economic development. When formulating our plans we must bear in mind that to lift the masses of our people from poverty we will need considerably more energy than we have been consuming in the past. This increase in energy consumption will likely take place in world markets of rising energy costs and growing shortages. For a developing economy to cope with such a situation the only way is to maximise national energy productivity. While we are going to use a lot more energy in absolute terms it will have to be considerably less per unit of production. Also we will have to use this increased volume of energy without inflicting unnecessary damage on the human environment.

Given these goals our task will not be easy and as I said at the outset we must keep pursuing it until answers are found. This and similar workshops are phases on this bumpy ride and I hope that this workshop will shorten considerably the remaining distance to be travelled.

ANNEX III
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