The Need for Alternative Sources of Energy in Sri Lanka.

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"Energy is the 'sine qua non' of a modern society's ability to do the things it wants to do. While lower energy costs allow a society more freedom of action in seeking its goals, the availability of energy is the first requirement of having any freedom of action at all."

ENERGY CONSUMPTION

The total energy consumption in Sri Lanka for the year 1977 was estimated at 10,000 GWh (electricity replacement) of which 1200 GWh was provided by hydro-electricity, 2800 GWh from oil products and 6000 GWh by traditional fuels such as firewood and agricultural residues. The natural solar energy radiation is excluded from this assessment.

ELECTRICITY

The demand for electricity which grew at about 6.5% per annum around 1970 to 1975 is now growing at about 14% per annum. Plans for installing hydropower plants were based on a 10% per annum growth rate. The per capita annual consumption of electricity which is around 110 KWh is low compared to that of our neighbouring countries like India, Thailand, Indonesia and the Philippines (between 200 and 400 KWh) and much lower than that of the developed countries like Canada and the United States of America (around 8000 KWh). Besides, only about 11% of the households and about 8% of the villages in Sri Lanka have access to electricity.

On a very broad average, in the developing countries, the demand for electricity doubles itself once in 7 years, while in the developed countries the doubling period is 10 years. There are many developing countries that have experienced sharp growth rates in electrical energy demand. In Thailand, the demand for electricity grew threefold from 1967 to 1974. In Bulgaria, the percapita annual consumption of electricity grew from 45 KWh in 1944 to 2230 KWh in 1970. In Egypt, the electricity grid grew from 348 MW in 1952 to 4100 MW in 1970.

With emphasis on rural electrification programmes and on industrial ventures, the demand for electricity in Sri Lanka is bound to rise sharply in the near future.

The Accelerated Mahaweli Development Programmes, which would be bringing into stream Bowatenna (40MW) in 1981, Canyon (30 MW) in 1982, Kotmale (134 MW) and Victoria (210 MW) in 1984, Randenigala (122 MW) in 1986 and Rantembe (49 MW) in 1987 would be meeting the growing electrical energy demands till about the year 1988. Owing to the sudden growth of electricity demand since 1977, it has also become necessary to install 60 MW of gas turbines by the end of 1980, and another 60 MW by the end of 1981. The development of these hydroplants in series would be followed by the development of Samanalawewa (possibly 240 MW and 400 GWh) around 1989 and the remaining hydropower resources which have an aggregate potential of around 750 MW and 2300 GWh/annum energy in quick succession thereafter.

THE ELECTRICAL ENERGY GAP

A gap will emerge around 1988 between the demand for electrical energy and the development of the hydro resources. This gap will widen very rapidly towards the end of the century. It will have to be filled by non-hydro sources of electrical power generation.

OIL

The petroleum requirements of the country are met mainly by the refinement of crude oil into middle distillates at the refinery at Sapugaskanda. A certain amount of kerosene and diesel are also imported from time to time to supplement the needs above what we convert from the crude oil imports. The heavy ends left over after the extraction of middle distillates from the crude oil is used for industrial heating and bunkering facilities. The introduction of secondary refining processes like the hydro cracker would convert the heavy ends also into middle distillates and save further importation of refined diesel and kerosene to meet the demand.

The bunkering facilities could be catered to by the international markets where bunker oil today

fetches depressed prices. The demand for diesel will rise with its further use in the Gas Turbines to generate electricity and for transporting and operating heavy machinery in the accelerated Mahaweli Programme, in addition to its normal increasing demand in the transport sector.

The crude oil imports over the last ten years have been around 1.5 million metric tons per annum. But the cost of these imports have risen over tenfold. It therefore becomes very clear that we will have to minimise our dependency on crude oil imports.
It will be difficult to find a substitute for petroleum in the transport sector. Ethanol is currently more expensive than petroleum. Besides, the availability of land and the more urgent need to become self sufficient in sugar will preclude the use of ethanol, in transport. We should therefore aim at replacing petroleum products in industrial heating with alternative sources of energy, conserve the use of petroleum in the transport sector, and introduce secondary refining processes in the refinery to optimise the use of crude oil imports.

FIREWOOD

Firewood constitutes 60% of our energy needs. 94% of the households in Sri Lanka use firewood for domestic cooking. Nevertheless, the efficiency of its use in domestic cooking is very low.
The need to devise and popularise an efficient domestic cooker is imperative, in order that the existing firewood resources could meet the growing domestic need. Over the past few years, we have been consuming more firewood than what the forests can naturally regenerate. This is evident by the depletion of the forest cover from 45% of our land area in 1958 to 25% today. This trend has to be arrested very quickly. The Ministry of Lands and Land Development is already taking giant strides in protecting the forest cover and embarking on a planned forest programme. The Ceylon Institute for Scientific and Industrial Research (CISIR), the Industrial Development Board (IDB) and the State Timber Corporation are engaged in making more efficient domestic stoves and in the better use of fuelwood in domestic cooking.
The use of biogas generators in re-cycling animal and agricultural wastes for the generation of methane on one hand, for its use in smallscale electricity generation or domestic cooking, and for the production of a higher value fertilizer on the other hand-which will reduce our need to import fertilizer — should also be encouraged.

NEEDS SUMMARY

In summary we note :

1. A gap would arise beginning around 1988 between demand for electricity and planned hydro energy development which will widen towards the end of this century. This gap has to be bridged by electricity generation from non-hydrosources.

2. Secondary refining processes should be introduced in the refinery to optimise the use of crude oil imports.

3. The replacement of the use of petroleum products for industrial heating should be pursued.

4. Conservation measures should be introduced in the use of petroleum for transport.

5. We should devise and popularize a more efficient domestic fuel wood cooker.

6. We should embark on a planned reforestation programme.

ALTERNATIVE ENERGY SOURCES AVAILABLE TO US

We now examine the alternative sources of energy that are available to us.

Sri Lanka has so far not discovered any coal, oil or natural gas. Some peat resources in Muthurajawela have been analysed. The availability of peat in other parts of the country have not been analysed. Being a tropical island we receive plenty of sunshine. Certain parts of the country experience strong wind regimes. Uranium and thorium deposits are found in some parts of the country. We encounter small tides. Only about half of our hydro power resources have already reached a level of planning and exploitation.

(i) **Hydro resources.**

The remaining hydro resources should be systematically planned for its exploitation in the 1990's in quick succession.

(ii) **Peat resources.**

A systematic study should be made on the available peat resources in the country.
An analysis of peat resources in the Muthurajawela reveals that about 2 million tons of peat of 40% moisture and of a calorific value of about 2,600 K cals/kg is available. Peat may be used to supplement coal in a coal fired power generating plant. It may also be

converted into briquettes of 15% moisture and calorific value 5,600 K cals/kg for domestic use.

(iii) **Nuclear Resources.**

Sri Lanka has some uranium and thorium resources. There will be a scarcity of uranium resources to meet the world need for nuclear reactors in the commercial burners in the 1990's. However commercial nuclear power plants that could compete with oil fired plants are of the size of 600 MW (e) or more. The Sri Lanka electricity grid will not be large enough to accommodate a 600 MW (e) nuclear power plant even by the year 2000. A 300 MW (e) nuclear plant may be accommodated in the grid by about the year 1995. However a series of feasibility studies and other scientific studies have to be conducted before a nuclear power plant can be recommended for the grid. Sri Lanka does not possess qualified scientific staff to carry out these studies. The staff should be familiar with basic nuclear physics and be trained in nuclear power technology. The lack of qualified staff does not permit Sri Lanka to introduce nuclear reactors before the year 2000. The alternative, of course, is to depend on foreign expertise which will make nuclear power generation prohibitively expensive.

(iv) **Solar Energy Resources.**

The average solar insolation per day in a dry region of Sri Lanka is about 5 KWh per square metre. Central Solar Energy electricity generating stations will not be developed for commercial use before the year 2000. However solar energy may be used in decentrallised systems for various uses even today. Photo-voltaic cells are expected to come down in price in about five years. This subject deals with the interaction of photons with matter and therefore calls for a deep understanding of theoretical physics. Photo-voltaic cells may be used to power VHF radio links between remote post offices and rural exchanges. Solar panels may be used for heating and cooling in buildings. Solar stills may be used to produce potable water for remote households and distilled water for car batteries and science laboratories. Solar refrigeration may be developed to preserve fruit and vegetables. Solar driers may be used for drying grains, cashew nuts, copra, pepper, tea and timber. Solar pumps may be used to lift water for irrigation purposes. These technologies require some capital investment in hardware for collection and conversion into useful forms.

(v) **Wind Energy.**

There are certain areas in Sri Lanka with strong winds. Wind energy is best used for lifting water from the underground for irrigation purposes.

(vi) **Biomass.**

Biogas generators may be used to recycle animal and agricultural wastes to generate methane and a higher value fertiliser. Methane may be used for domestic heating or small scale electricity generation. The use of biogas generators is now becoming popular in Sri Lanka.

(vii) **Ocean Thermal Energy Conversion (OTEC).**

The use of the temperature difference in the surface and bottom waters of the oceans to generate electricity is still in its early experimental stages. Commercial plants could be expected only in the next century. Preliminary investigations indicated that Sri Lanka could possess possible OTEC sites.

CONCLUSION

The need therefore arises for us to make a complete study of the alternative sources of energy that will be available to us. Of course, we should determine what our priorities are. At present, we have a 1980 to 1984 investment programme. It is a rolling programme revised every year. The 1981 to 1985 investment programme is in the making. We should, at least in the energy field:

1. Ensure that the manpower and financial resources are available to complete the current plans in the first instance.
2. Plan a proper reforestation programme. These plans would yield results only after many years.
3. Plan the optimum use of remaining hydropower resources and their phasing.
4. Introduce secondary processing facilities in the oil refinery.
5. Plan for the use of coal/peat/wood for electricity generation in 1990 to 2000, to bridge the gap that would arise between electricity demand and the availability of hydropower.
6. Plan the use of alternative sources of energy for industrial heating.
7. Plan on a conservation programme for oil, electricity and firewood.

The first priority is to have a comprehensive plan at least in the energy sector for the decade 1980 to 1990. When the manpower and financial resources are determined for the decade 1980 to 1990, then the next priority should be to plan for the decade 1990 to 2000. When the manpower and financial resources are determined for the decade 1990 to 2000, only then should one plan for the decade beginning 2000. The 'R + D' allocation in any plan should be confined to areas that would be considered priority areas 10 or 15 years hence but are not considered priority areas today.

The views expressed by the author are personal and need not reflect the views of either the Ministry of Finance and Planning or the Government of Sri Lanka.

Solar Thermal Energy for Sri Lanka

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Energy is not a primary need for us other than in the form of food. Food itself is a significant component of energy consumption. We need energy for transportation, for the construction, operation and the maintenance of vehicles. We need energy for heating and cooling. There are many other needs of energy for the additional comfort of man and also for the machinery needed to replace or supplement human muscle power.

There is no substitute for energy which has to be met either by our accumulated sources or renewable sources. Energy, in most cases, is not an end product and hence one of the simplest and most satisfactory way of economising on energy is through a better utilization of it. That is to achieve the same end results using less energy.

Each of us is constantly burning up food as fuel for the human machine, at the rate of about 120 watts. The energy that is utilized to produce our food is very much greater than this. For vegetable food, the basic energy source is solar. In order to grow food, irrigation, fertilizer, tractor, human effort, etc., are needed which has to be paid for and these too consume energy. Thus the total energy input may be 50 times higher than the amount we burn in our own bodies. There is also a great contrast in energy usage between industrialised and developing countries. In developing countries, it is about 300 watts per head and in the developed world it is 5 kw per head.

Apart from the energy used directly by man, there are indirect uses such as industrial processes in making cement, steel and aluminium, plastic, glass, etc. All require high temperature heat energy. The demand for energy can be classified as low temperature, high temperature and motive power. It can also be divided into domestic, transport and industrial use.

WORLD ENERGY SUPPLY

Before the industrial revolution, the chief source of heat was firewood, while human and animal food were needed partly as a basis for motive power in the form of human or animal muscular effort. Food and firewood both derive their energy basically from solar radiation. The maximum incident amount of solar energy is nearly 1.35 kw per sq. metre on the topmost layer of the atmosphere. Averaged over all latitudes and throughout the day it is a quarter of this value. Over three-quarters of it falls on the oceans where it is directly exploited only through fishing. More important from our point of view is the resulting evaporation which leads to rain.

A major portion of the sun's radiation incident on land falls on areas which are infertile due to extreme climatic conditions. Much of it is reflected back into space by the atmosphere, but some of it is eventually absorbed by the air causing the winds, which to a small extent we can exploit directly but which are vital for us, mainly by bringing the water evaporated from the oceans over land, and so making it fertile.

Wood is another ready source of medium temperature heat, and with moderate rate of use forests are self replenishing. However, wood cannot be used for high temperature applications such as for the manufacture and shaping of iron. For centuries the chief high temperature source was charcoal, then coal and now oil. At the present rate of exploitation, our coal resources are sufficient for about 250 years and oil for only 30 years.

The sun is the direct or indirect source of various renewable energy sources such as solar, hydro, wind, wave energy and ocean thermal gradient. There is a long history of exploitation of wind power until it was replaced by coal. In Sri Lanka, we use one of these sources, namely hydro, for most of our electricity needs.

EARTH AND SOLAR SYSTEM

The earth is a very small portion of our solar system and the sun in turn is an insignificant spark in a galaxy and several such galaxies constitute the Universe. The sun in spite of being 150 million km away, provides us warmth on a daily basis, to raise crops, and to produce coal and oil in the past. It also exerts control over our climate which results in using up scarce fuel for winter heating and cooling in summer. Bad weather also leads to floods and droughts which also drains on our energy resources in removing flood water and providing irrigation. Photosynthetic conversion of solar energy also provides the vegetation that is widely needed for the existence of mankind. It is clearly evident beyond doubt that the energy needs of man cannot be discussed without reference to the sun.

SOLAR ENERGY

A satisfactory standard of living is possible for all of us using this virtually inexhaustible energy resource. The solar radiation incident upon the earth everywhere is 5×10^{24} joules, many orders of magnitude greater than our world energy use per annum which is around 2×10^{20} joules.

Solar energy can be utilized in different ways. There are direct methods where the incoming solar energy is converted into another form such as heat or electricity and indirect methods such as exploitation of kinetic energy of wind and waves and potential energy of rainwater.

Storage poses the most difficult problem in the usage of an energy resource. On the one hand, our society requires energy in a fluctuating fashion on demand, and on the other hand our energy sources must have the most economic patterns of energy production. Solar is most economic in supplying energy in daylight hours. In between the source and the user some storage system must be used. This accounts for a substantial portion of the cost of energy.

At the earth's surface, the intensity of solar energy when the sun is directly overhead on a clear day is about 1 kw per sq. metre. The average daily incident solar energy is about 5 kwh per sq. meter in Sri Lanka. This figure may be around 3 kwh per sq. meter for England, and that too is less evenly distributed over the year. However, one should note that a a substantial portion of our incoming energy is in the form of diffuse radiation which cannot be used in a concentrating type of collector. Therefore, for major use in Sri Lanka we should rely on non concentrating flat plate collectors.

SOLAR THERMAL ENERGY FOR SRI LANKA

There are many devices used in the conversion of Solar Energy into Thermal Energy. These can be broadly categorised as follows :—

1. Non—concentrating Collectors
   (*a*) Low Temperature
   (*b*) Medium Temperature

2. Concentrating Devices
   (*a*) Medium Temperature
   (*b*) High Temperature

Most prominent among the non—concentrator is the flat plate collector. A simple, single glass, black painted, flat plate collector is capable of generating hot water for low temperature application upto about 60°C. The National Engineering Research and Development Centre (NERD) had done extensive studies on this type of collector, selecting the most economical materials available in the local market and the type of of collector best suited for our climatic conditions. The conversion efficiency of solar radiation to heat at 60°C of the collector developed at National Engineering Research and Development Centre is around 60%.

The Medium Temperature flat plate collector requires much more sophisticated manufacturing technology. These normally use double glass and selectively absorbing surfaces. These collectors are mainly used for application such as refrigeration, air-conditioning, pumping and for solar engines. However they do not offer higher efficiencies than ordinary flat plate collectors at low water temperature. At medium temperature applications, their performances are much superior. This type of collector is still beyond our manufacturing capability. Even India has not yet commenced the commercial manufacture of this type of collector.

Concentrator types are essential for high temperature needs. These are more expensive due to the necessity of tracking the sun and also the sophistication involved in the manufacture. The NERD Centre has experimented with several of these concentrators and is at present installing a 30 kw steam generating plant.

Even though we have a relatively high degree of solar radiation compared to the high latitude countries, about 50% of our radiation is in the form of diffuse radiation, which cannot be focused in a concentrator type of collector. This fact makes the concentrator less suitable compared to flat plate collectors unless the end use demands a high temperature, which cannot be achieved with a flat plate collector. There are several other collecting devices such as non-convecting solar ponds which are still in the experimental stage.

Under our conditions, the most promising area of solar thermal application is in our industrial sector. This is in contrast to most of the developed world where the emphasis is on comfort heating due to their extreme weather conditions. As such our R & D efforts should be on a different line to those of the developed world.

A substantial portion of hot water requirements in our industry mainly food processing, dairy and textiles is below 60°C. These hot water requirements can be easily met with solar collectors during sunshine hours and at other times using the conventional fuels. Another important requirement of energy in our industry is steam. In this area too, solar energy can be used in pre-heating boiler feed water. NERD Centre has conducted a few energy surveys in the public sector industries with a view to identifying possible areas for the use of solar energy. The results are extremely encouraging and has a programme of extending this facility to other industries as well. The boiler feed water heating system has the additional advantage of not requiring hot water storage and automatic controls usually needed for such systems. The estimated capital pay back period for such a system is less than 4 years, based on the current price of fuel. Already a leading private sector industry has commenced the installation of flat plate solar collectors for heating boiler feed water. There are indications that many other industries will follow suit.

In the domestic sector, the energy needs such as lighting, cooking and other forms of human muscle replacement, machines cannot be conveniently met with by solar energy. Unlike in high latitude countries, we do not require central heating or hot water. As such the use of solar energy in the domestic sector in Sri Lanka will be minimal.

However in the tourist industry and hotels, there is a growing demand for hot water below 60°C. This can be very conveniently met with the type of collector described earlier. India has made substantial progress in this sector and their experience can be very valuable to us. Here too the NERD Centre could assist the tourist industry in the manufacture and installation of solar collectors with electrical or oil fired boosters. These will take care of rainy weather and night time hot water needs.

In the agricultural sector, solar drying can be of great assistance to the farmer in providing a cheap and more hygienic way of crop drying. Solar pumping and solar refrigeration can also be economical in remote areas where the national electricity grid has not yet been reached. Even the domestic lighting can be met with by solar photo—voltaic cells. However these applications are not as attractive as those in the industrial sector.

ENERGY CONSERVATION

As mentioned earlier, energy is not used as an end product but used in producing other forms of end products. As such, efficient methods of production will result in a substantial saving of energy. To meet this end we have to revise our manufacturing and production techniques and new industries should be evaluated on the basis of their energy efficiency.

Energy conservation starts with some one taking a closer look at the energy flow of the industry. This involves drawing up of a complete energy balance of the industry, the type of energy used, where it has been used, how efficiently it was used, etc. Such a study forwarded to the management indicating the energy accounts in terms of money as well as joules will greatly help in the decision—making process. To take a simple example, a recent survey carried out in a U.K. paper mill showed that the steam whistle of the mill which cost £2 for each blow, blows 4 times a day. When this was pointed out they decided to stop it. Similarly if a trained observer can point out to the management that through a leaking steam joint, the Company is losing so many gallons of fuel per day (1 gallon of fuel is needed to generate 100 lbs of steam) all possible action will be immediately taken to stop the leak.

The NERD Centre has carried out several studies in energy auditing in public sector industry. This facility can be made available to any interested industry either public or private by the NERD Centre.

Solar Desalination

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In spite of the large quantities of fresh water supplied by rainfall in Sri Lanka, there is uneven distribution of rainfall in many regions. In some arid areas, even ground water is brackish and no other source of drinking water is available. Hence there is a definite need for distilled water for drinking purposes although such requirements are limited. Also, distilled water would be required in lesser quantities for lead-acid batteries and for chemical laboratories.

Vapour compression desalination, electrodialysis and flash distillation are some of the existing methods of producing fresh water. However, these techniques involve high capital investment and utilise conventional energy sources.

Solar energy can be used for desalting of saline or brackish water. Solar distillation does not produce water where there is none but simply purifies water supplies in areas where there is adequate water which is unfit for human consumption or other activities. Solar distillation plants have been known for more than a hundred years. The first solar still was established for the mining community in Las Salinas, Chile, in 1872. Exhaustive development work on solar stills have been carried out only in recent years and the largest one in operation today covers an area of one hectare and is situated in Greece.
Solar stills, however are not yet competitive with conventional desalination plants. Considering the transport costs or supply of water by pipe lines in remote areas where no other source of drinking water is naturally available, small scale stills may serve its purpose and be economically feasible.

Sri Lanka is situated 8^0 N latitude, and is blessed with sufficient sunshine where the intensity of solar radiation could vary between 300 to 500 cals to cals/cm^2 /day during the year. Hence due to the abundance of solar energy, solar distillation could suffice when water requirements are small and no other cheap energy source is available for desalination.
Thus development work on solar stills was carried out at the Ceylon Institute for Scientific and Industrial Research (CISIR) with a view to setting up of small community stills to provide drinking water and also providing distilled water for lead-acid batteries and chemical laboratories.

THE WORKING PRINCIPLE

The simplest type of solar still is the basin type which consists of a shallow basin covered with a transparent roof (Fig. I). The basin is coloured black and the saline or brackish water is introduced on to this black surface. Incident solar radiation passes through the transparent cover and is absorbed on the black bottom and provides the heat to evaporate the saline water. Water vapour moves upwards towards the transparent covers which are cooler and condenses on the underside and rolls down into channels and is collected in receivers.

The shortwave radiation of visible light is able to pass through the transparent cover but the longwave radiation of heat does not. Thus most of the heat generated in the still is trapped as longwave radiation emitted by the hot water which cannot escape through the cover to the outside. The temperature in the still raises steadily and stabilizes when the heat losses to the outside equal the incoming radiant energy.

Part of the solar radiation falling on the still is reflected or absorbed by the cover. The energy falling on the evaporation surface is not completely used for distilling but is lost by reflection, convection, radiation from the covers and through conduction from sides and bottom. Any leakage of vapour of liquid from the still involves additional thermal loss. Due to losses and the diffuse and intermittent nature of solar radiation, the efficiencies obtained in practice are low and the output of a solar still per unit area is low. Efficiency is calculated in the following manner.

$$\text{Efficiency} = \frac{\text{Energy required for vaporization of distillate that is recovered}}{\text{Energy in the sun's radiation that falls on the still}}$$

EFFECTS OF CLIMATIC FACTORS ON SOLAR STILL PRODUCTIVITY

Intensity of solar radiation, ambient temperature, annual rainfall and wind velocity are four major climatic factors that influence the productivity of a solar still.

The most important factor affecting the solar still performance is the intensity of solar radiation. The higher the intensity, the greater is the distillate output. As the direction and intensity of solar radiation impinging on the still varies throughout the day for various months of the year, the output varies both by hour of the day and by season.

The solar energy received on the earth is a combination of radiation from the rays of the sun (direct radiation) and energy originating from the sun but scattered by clouds, or dust particles in the air (diffuse radiation). Although in a solar still both direct and diffuse radiation are utilised, most of the energy available for distillation arrives as direct radiation. The maximum direct radiation occurs at the hours and seasons when the sun is directly overhead. During the day this occurs at noon and radiation intensity is nearly zero in the early mornings and late afternoon hours. Hourly productivity in a solar still follows the solar radiation intensity pattern but lagging behind it. This is due to the time lag in heating and cooling the water within the still.

Higher ambient temperatures increase the output of solar still slightly. Rainfall will stop the

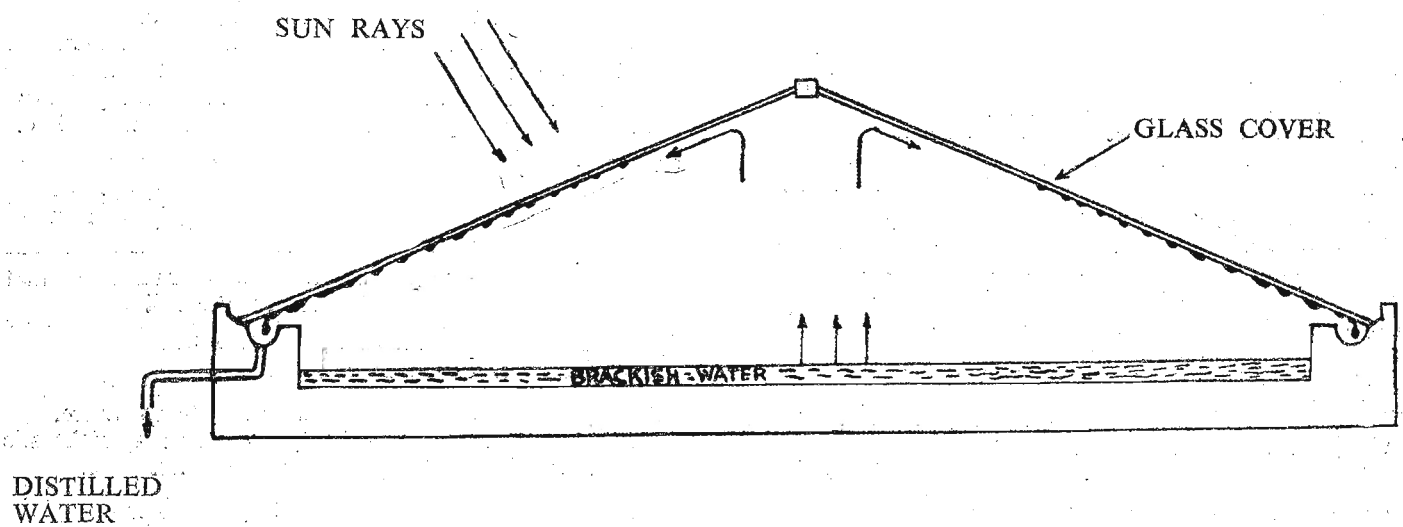


FIGURE 1 BASIN TYPE STILL

production of solar distilled water but a solar still cover could be used as a catchment for rainfall which could compensate for the loss. High wind velocities tend to cool the covers rapidly, thus lowering the temperature of the still, which in turn would decrease the productivity.

EFFECTS OF DESIGN ON PRODUCTIVITY

The basin type still is generally accepted as the best design in that it is the most economical and practical. Brine depth, vapour tightness, condensate leakage, basin insulation are factors which could appreciably affect the productivity of a still and to a lesser extent cover slope and elevation.

Shallower brine depths reduce the heat capacity of the still, thus giving higher brine temperatures, resulting in increased productivity. However nocturnal output is greater with deep layers. This is due to the fact that the large heat capacity of the brine layer causes water temperature to rise to a lower value and distillation proceeds slowly until a lower water temperature is reached. Hence distillation after sun set accounts for a larger fraction of the total. In contrast, the high rate of distillation during sunny hours in the case of shallow brine depths causes rapid cooling of water so that soon after sunset the temperature of water becomes too low to cause evaporation and night time distillation is a minimum. However, the total productivity in a day seems higher for shallower brine depths. In our experience, a brine depth of 2.5 cm seems adequate to ensure that there will be no dry spots due to an uneven basin bottom and also to give maximum productivity.

Vapour tightness is very important in the construction of a solar still. Sealants should withstand extreme environmental and weather conditions so that the still performance may not deteriorate with time. Although silicone sealants have been widely used in developed countries, our efforts in using bitumen based materials have proved successful in minimising vapour leaks. However, proper care in application of these sealants is important.

Loss of condensate through cracks in condensate collection channels is common where aluminium, concrete, etc., have been used for the channels. However, we have eliminated such losses in metal and concrete channels by lining with an ebonite compound made of natural rubber. Also these channels should be deep enough to prevent losses by overflow.

Basin insulation to prevent heat losses from the bottom and sides of the basin is necessary for maximum efficiency. However, it would not be economical to insulate large ground based solar stills. To overcome this difficulty, lining of the basin with butyl rubber has been widely accepted as it provides the black surface as well as acts as an insulator for heat conduction towards the ground. Our investigations with a substitute of ebonite compound made of natural rubber has given excellent performance over a period of 16 months to date. Commercially available rubber sheet (1/4" thick) has given good results over a period of 8 months so far.

For the transparent cover, although plastic and glass has been used, glass has proved to be the best. Also, symmetrical double sloped cover set at an angle between 10^0 to 20^0 to the horizontal is most suitable. The cover angle is so chosen to minimise the direct radiation reflected back to the atmosphere and also allow sufficient slope for the distillate to run down The glass cover should be close to the evaporating surface of water for efficient distillation and also to minimize shadowing from supports.

CONSTRUCTION MATERIALS

Construction materials used in solar stills are those generally used in civil engineering works. Such materials should be strong to resist strong winds, rain storms and have a long life. The basin and distillate channels should be made out of material that would not corrode or contaminate the distillate. Wherever possible, local materials should be used which are of light weight and can be transported easily.

Cover material should be highly transparent to short wave radiation and nearly opaque to long wave radiation. Its surfaces should be wettable, so that water would form a film on it rather than droplets. The material should not absorb water, absorb or reflect large amounts of solar radiation and should be able to withstand high temperatures (100° C), shock caused by wind blown debris. Glass is nearly ideal for covers as it satisfies nearly all the above requirements. Transportation of glass is difficult due to its fragility and is quite expensive in Sri Lanka. Plastic materials have been proved to be far inferior compared to glass although they could be transported easily and quite cheap in other countries. Transparent plastic materials are not readily available in Sri Lanka and are expensive. Therefore for our investigations 3/16" thick window glass was used.

The evaporator basin which contains the saline water should be black on its surfaces which have a high absorptivity for solar radiation, must be watertight, should not corrode or deteriorate at high temperatures (100° C) or for the salinity, should be abrasion resistant and easily cleaned. Experimental investigations were carried out using aluminium, PVC, G.I., concrete, asbestos cement sheet, G.I. with rubber lining, concrete with rubber lining for the evaporator basin. Concrete with rubber lining is the most acceptable as the efficiency is high and cost is low. This is the type of basin recommended in our design but further work is proceeding with commercially available rubber lining.

The supporting structures required for the still should consist of a good structure for the base and a frame for transparent cover. The material used should be strong enough to resist winds, their thermal expansion should be low, and should be easily handled in the field. The cover frame should be made out of members of small thickness to avoid excessive shading for the basin. Well seasoned hard wood like Halmilla, Palu or even Jak were found to be suitable for the cover frame and have lasted nearly five years without deterioration. Concrete or brickwork for the still foundation and basin were found suitable.

The distillate collection channels should be made of materials that are not attacked or corroded by the distillate or contaminate or add taste to the distillate. Metal, plastic and concrete have been used as construction material for the channels. If the base of the still is constructed in concrete it would be very convenient to construct the channels with cement. However, as the cement is not completely impervious to water, in our construction we have used a rubber lining to make it waterproof and have proved successful.

Sealants are being used to hold the cover to its frame and also make the whole still airtight. Such sealants should be able to absorb the expansion and contraction of the cover and frame and the base. They should form a good bond between glass and other materials used, resist weathering and aging while remaining flexible and should possess ease of application. Window putty, asphaltic compound, silicone sealants or even cotton adhesive tapes, rubber have been used as sealants but most accepted ones requiring low maintenance are silicone sealants and asphaltic compounds. We used a sealing compound with the trade name 'No leak' as it is readily available. Silicone sealants are reported to be the best. Special care should be taken in the application of 'No leak' and little maintenance is required.

Insulating materials are generally used to prevent heat losses from the bottom and sides of the basin. Such insulation is necessary only when metal basins are used. If concrete is used with a lining of rubber, insulation is not necessary as heat conducted down is low.

SITE SELECTION AND PREPARATION

In installing a solar still, a suitable site should be selected to avoid problems during normal operation. The selected site should be level firm land where the sunshine is unobstructed by trees, buildings, etc. The still should be constructed with one edge running parallel to the east-west direction, and should be close to the supply of saline water but places where sea spray can cover the transparent cover should be avoided. The site should be fenced with cadjan so that excessive wind could be cut off and also to prevent damage to the still by wind blown debris and to keep out children. However the fence should be sited at a distance from the still to avoid shading.

The land should be cleaned, levelled and treated with a herbicide.

STILL CONSTRUCTION

The ground should be dug and the foundation laid with brick work with a mixture of cement:sand about 1:4. The basin should be given a plaster coating of cement : sand mixture of 1 : 2 mixed with water proofing additive of pudlo. The ebonite compound which is made in sheet form should be held on to the surface with an adhesive. The vulcanisation is done by exposure to sun's heat for about seven days. The distillate collection channels should also be given a coating of the solution of the ebonite compound and allowed to cure under the sun's heat. The roof structure either made of precast concrete or hard wood is placed in position on the still and the glass covers are placed on the frame structure. The lower end of the glass would rest on the distillate collection channels. The glass covers are well sealed on to the frame with 'No leak'. The glass covers at either ends are fitted last with the lower end resting on the distillate collection channels and well sealed.

The piping for saline water feed, distillate collection, rain water collection and basin drain off should be incorporated during the construction of the basin.

OPERATING INSTRUCTIONS

The concentrated brine left over from the previous day's distillation should be flushed out by opening the drain valve and pouring in a few buckets of feed water so as to remove any possible sediment that has settled. This should be done every morning before 7.00 a.m. and the still filled to the required height with the brine. The glass covers should be wiped with a cloth to remove any dust that had collected. The distillate collection vessels should be emptied and the collected water measured to keep a check on the productivity of the still. If there is a decrease in the productivity any faults could then be detected.

The feed water should be poured into the feed tank through a cloth filter to remove any mud or sand getting into the still If there is much sediment in the feed, the feed tank is provided with two compartments so as to allow overflow of water into the second compartment free of sediment This compartment could feed the still. Periodically, the vertical covers at the ends of the still should be removed and sediment collected on the basin should be removed with a brush. Since the distilled water collected is free of minerals, certain amount of the saline water could be added to the distilled water before consumption.

PILOT PLANT

After the laboratory trials on small stills, a pilot plant was set up at Sarvodaya Centre in Pungudutive, Jaffna. The village of Pungudutive is starved for good drinking water and siting the pilot plant here was not only to study the performance of the large scale still but also to study whether such devices would be acceptable to the population.

The still was $3m^2$ in basin area and was constructed of brick work and the glass roof was mounted on a wooden frame. The basin was lined with ebonite compound of natural rubber. The cost of construction of the still was Rs. 2,000/-. On an average this still gave an output of 9 litres per day.

CONCLUSION

Experience in the design and construction of solar stills were gained during the laboratory trials. The materials suited for local conditions were chosen and the design for construction of large stills arrived has proved acceptable on pilot plant scale. On an yearly average the productivity of the still is about 3 litres per square meter per day. Although the initial cost of the pilot plant was Rs. 2,000/-, assuming it has a life span of ten years, the cost of distilled water would be about five cents per litre. The maintenance cost is virtually nil. The still being constructed out of brickwork, wood, glass and rubber, the durability of the wood and the rubber lining has to be tested for a few more years.

The Pungudutive population has shown great enthusiasm over this method of distillation and are interested in having many more stills set up for individual families as for community use. Generally it would only be possible to set up community stills and not home units due to space and shading problems.

Power from the Wind

K. S. Fernando

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It is widely believed that by the turn of the century the cost of a barrel of oil would exceed US $ 100.00. This means that oil which served man for decades would be beyond the reach of a large number of developing countries and would be a costly source of energy even for the developed countries. Besides the fact that oil is a fast depleting resource, the volatile political situation in the Middle East which supplies the major volume of the world's oil requirements could seriously influence the future oil supplies and its price factor. In this context, the urgent need to search for alternative sources of energy to fulfil the energy demand of the country cannot be overemphasized. Harnessing the infinite quantum of energy in the wind is only one such alternative. This paper outlines briefly the state of the art in a global context and describes the approach of the Water Resources Board in this direction.

Wind Power

The source of wind is in the atmospheric temperature differences generated by the sun which in turn gives rise to pressure differentials. The wind is a mechanism for dissipating as kinetic energy the potential energy accumulated in those pressure differences.

For centuries, mankind has used wind as a source of power to propel his boat, draw water from the ground, to grind his cereals and for various other needs. There is evidence that the ancient Egyptians used windmills as early as 3600 B.C. to pump water to irrigate their arid fields and to grind grains.

But, with the invention of more efficient machines which have a higher power to weight ratio, obviously, the ancient windmills got gradually pushed aside as a source of power. As this happened in the very early stages of the development of science and technology, not many scientific studies were made on windmills. However, the beginning of the 20th century witnessed several renewed attempts to revive this technology with the help of the then available scientific knowledge derived mostly from the aircraft industry. But as the industrialised countries at that time had a strong political and economical control over the oil producing countries, the need to develop alternatives was not taken as a matter of serious concern. Thus these attempts which were mostly initiated by enthusiastic influence failed to gather momentum, mainly due to the lack of governmental support. However, though at the lower level of activity, research on wind power was continued throughout the past few decades. As a result, today the use of windmills could be considered both technically and economically a viable proposition, specially for such small scale application as water pumping and domestic lighting in rural areas.

Wind Energy Utilisation Project

During the past two years, the Wind Energy Unit of the Water Resources Board has been conducting a research programme with a view to introduce the technology of windmills to Sri Lanka and thus promote its wide use for small scale power needs in various economic activities in the country. This project is assisted by the Government of the Netherlands through the Netherlands Steering Committee on wind energy for developing countries by way of providing expertise and equipment.

Objectives of the programme could be classified as follows:

(1) Assessment of the wind potential in different regions of the country.

(2) Carry out feasibility studies for the use of wind power as an alternative source of energy for water pumping in the rural agricultural sector in Sri Lanka.

(3) Design and develop windmills for water pumping for local manufacture using local raw materials to a maximum.

(4) Introduce the technology of windmills to Sri Lanka and thereby promote its manufacture and application through an organised extension service.

(5) To organise a technical body and train its personnel in Sri Lanka for further development of the technology of windmills, locally.

Though wind power could be used for a variety of power needs, its application to agriculture was given priority as this sector still plays a dominant role in the economy of Sri Lanka.

Wind Potential in Sri Lanka

During the period from May to September, the entire Dry Zone experiences strong winds, the monthly average speed of which lies between 4 to 5 metres per second. The Hambantota District which records the highest windspeed in the country, experiences such winds almost throughout the year. Table I attached gives the monthly average windspeeds of a few selected areas of the country.

MEAN WIND VELOCITY

Table I

Units: meters/second

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Hambantota	5.73	5.47	4.36	4.00	4.76	6.62	6.40	6.62	6.49	5.11	3.82	5.16	5.38
Puttalam	3.22	3.28	2.66	2.97	5.17	5.91	6.10	5.71	4.75	3.18	2.08	2.78	3.98
Mahiyangana	0.92	1.10	1.06	1.03	1.56	2.94	3.10	2.98	1.79	1.36	1.21	1.08	1.68
Trincomalee	1.58	1.38	1.36	1.43	1.45	5.02	5.25	4.70	3.07	1.94	1.33	1.29	2.48
Jaffna	2.23	1.96	1.88	2.46	6.31	7.29	4.71	4.21	4.31	2.71	2.22	2.22	3.54
Polonnaruwa	1.70	1.42	1.43	1.50	2.77	4.22	4.53	4.08	2.56	1.84	1.82	1.79	2.47
Mannar	4.13	3.38	2.00	2.89	4.13	4.58	4.13	4.13	4.22	3.16	2.98	3.96	3.64

The power output of a windmill is directly proportional to the third power of the windspeed. There fore, when the windspeed doubles, the power output of a given windmill increases by eight times. This shows that a reasonable prediction of the output of a windmill requires an accurate long term analysis of the windspeeds of the particular area. As windspeeds vary from region to region, the small windmill under identical pumping conditions would give varying outputs in two different regions thus making the cost of pumping a variable factor. Therefore, when designing windmills much attention has to be paid to the aspect of matching the pump with the windmill taking into consideration the prevailing local windspeeds.

Design and Development Work

The design work carried out by this unit during the past two years has enabled this unit to produce two prototype windmill pumps. The following criteria were used as guidelines for the design of these prototypes:

(a) Maximum use of locally available materials

(b) Simplicity of the machine which makes manufacture possible with the basic machine tools which are normally found in workshops in remote areas.

(c) Designed windspeed to be matched with the average windspeed prevalent during the windy season in the Dry Zone. The basic parameters of the two prototypes developed within these constraints are given below :—

		I/2	II/2
(1)	Rotor diameter (M)	3	5
(2)	Tip speed ratio (—)	2	2
(3)	Tower Height (M)	6/9	6/9
(4)	Pump Diameter (M)	0.1	0.1
(5)	Stroke variable upto (M)	0.15	0.25
(6)	Output with a lift head of 10 metres at an average wind speed of 4½ metres per second	25-35 cu. metres per day	65-95 cu.m. per day

As the output of a windmill depends not only on the average windspeed but also on the speed fluctuations over the day, a generalised output prediction could only be made through long term field testing.

The tower of the windmill is a four legged bolted angle iron construction and curved G.I. sheets are being used as rotor blades. The tail vane mounted on an inclined hinge keeps the rotor always facing the wind. The machine is coupled to a simple reciprocating pump via a long pump rod which is properly guided inside the rising pipe. A reciprocating type of pump was selected for this purpose mainly because of the simplicity of manufacture and maintenance. However, its dynamic behaviour and the high starting torque makes its use possible only with slow speed windmills.

Economics of wind power

The power output of a given windmill depends entirely on the windspeed. The output of a windmill under identical conditions in two different regions varies with the prevailing windspeeds. Hence the cost of a 1000 gallons of water pumped for exam ple in Hambantota is different from that in Batticaloa Recently, a theoretical study was made by us to compare the cost of pumping with wind power with that by conventional kerosene pumps under identical pumping conditions. This study revealed that on the basis of annual costs, wind power is an economical alternative for water pumping in most parts of the country. However, with the escalating fuel prices, the relative cost of windpower would be on the decline, thus making it more and more attractive as an alternative source of power for water pumping. But the comparatively high capital cost of a windmill pump unit is the main factor retarding its wide application, specially at the level of the small scale farmer, who should be the ultimate beneficiary of this programme. Much attention is now being paid to this aspect of the project and it is believed that a scheme could be worked out in the future to provide financial assistance to farmers through banks. Reliability, performance and durability of these pump units are the key factors which have to be thoroughly studied under field conditions before any recommendation could be made to the banks to provide financial assistance for the purchase of windmills. In order to fulfil this, the Wind Energy Unit now carries out preparatory work in establishing a series of pilot projects in different areas of the country where there is a favourable wind potential.

Extension Services

Unlike the engines or motor driven pumps, the performance of the windmill pump is clearly defined by the local conditions such as terrain, wind speeds, existing buildings, trees, etc. Therefore, even the most efficient windmill when poorly matched with the load or badly located would give a low output. This is one of the reasons for the failure of several early attempts of using wind power in Sri Lanka.

Therefore, it is considered very vital to advise the public through an extension service unit, the proper matching and locating of windmills so that the highest possible energy extraction is obtained from a given windmill thus making it an economically viable unit.

Future plans of the project

After having gained sufficient experience in designing and manufacturing of small slow running windmills, the plan envisages the development of fast running and slightly larger windmills. Such machines with higher outputs would be more suitable for group activities such as lift irrigation projects or large scale farms. But the development of such machines would undoubtedly confront a whole series of new technical problems that are not normally found in slow running machines. It is unlikely that such a design would be available for commercial manufacture before 1985.

The Unit also plans to broaden its network of windspeed measurements in order to carry out an almost islandwide survey of the wind potential. The significance of such a survey is that it forms the basis for prediction of wind energy output in different regions of the country, which in turn determines the economic viability of the use of wind power.

Charcoal - An Alternative Fuel

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Independance from increasingly scarce and expensive fossil fuels has become a priority for Sri Lanka. This fact was brought to everyone's attention by the government decision to remove, at least partially, the subsidy on kerosene, diesel and fuel oil. The price rise that followed and the uncertainty of future price increases and availability has compelled many households and industries to look for alternatives. For the majority, the alternative has been firewood which is the most widely used renewable fuel. Unfortunately, the price of firewood has also risen hand in hand with kerosene and diesel prices, partly caused by the increased cost of transport. The general dearth of firewood, while also helping to push up the price means that firewood has to be transported over longer distances to reach the urban population. Therefore, with every increase in crude oil prices the cost of firewood (and of kerosene, diesel and fuel oil) will increase and we may very well be paying significantly more for these commodities by the end of 1981.

The time is opportune therefore to utilize a new type of locally renewable fuel in Sri Lanka. The new fuel is charcoal, expected to cost Rs. 2.00 per kilogram for wood charcoal and Rs. 2.50 per kilogram for coconut shell charcoal. Although it may be new to Sri Lanka, several countries in our region notably Thailand, Malaysia, Indonesia and several African countries have utilised charcoal for domestic cooking and industrial use for quite some time. The reason for their non-use in Sri Lanka is obscure but the low price of fossil fuels in the past would certainly have contributed towards suppressing their use.

Production of charcoal

Wood is converted to charcoal by heating to about 380° C in an inert atmosphere. The pit method has been the traditional method of carbonizing wood and coconut shells in Sri Lanka. This process is, however, inefficient and wasteful as only 15% (approximately) of the material is recovered as charcoal. The rest is consumed. The down draft type above ground level kiln provides for more efficient carbonization giving a yield of approximately 30% charcoal.

Wood charcoal has twice the heat value of wood, while coconut shell charcoal is slightly higher than that of wood charcoal.

Utilization of charcoal

Industrial use

Charcoal does not offer any direct advantage over firewood when used in an industrial type of furnace. In fact, due to the low efficiency of charcoal kilns it is less economical to use charcoal. It is only in situations where firewood has to be transported over long distances that charcoal has an advantage over firewood.

Domestic use

The advantages of charcoal for domestic use are many and varied :

* Clean burning — no smoke, no soot
* Double the heat value of wood
* Economical to transport
* Easy storage and handling
* Energy efficient in use.

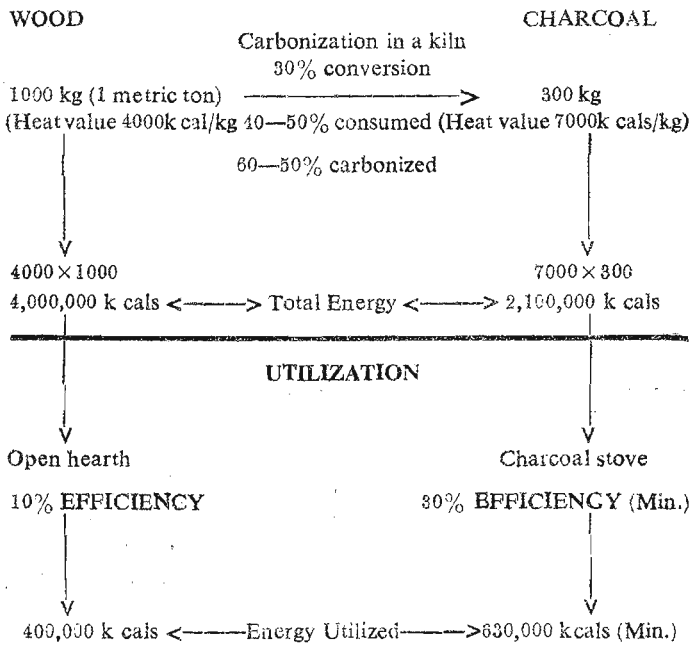
Clean burning — Compared to the firewood hearth or even the kerosene stove, the smokeless burning of charcoal is a definite advantage especially in an average urban house which lacks a kitchen with a chimney. Furthermore, apart from the fact that pots and pans will not need cleaning externally, use of a charcoal stove will improve the quality of life in a rural house. Usually smoke from the firewood hearth permeates throughout the house causing lung and eye diseases among rural women who are constantly exposed to large quantities of smoke.

Heat value — An extremely high heat is generated from charcoal producing a temperature of 550° C at the base of the cooking vessel. Cooking times will be equivalent to those with a kerosene stove or firewood hearth.

Transport — A major disadvantage of firewood is that it cannot be transported economically over long distances. The threshold distance for Sri Lanka is not known, but is thought to be about 80 km. With increases in the cost of diesel fuel, this distance will decrease. Once the wood is converted to charcoal, the threshold distance is automatically increased by a factor of two or more, making transport economical even up to 200 km. This situation applies to waste timber from the Mahaveli Development Zone. State Timber Corporation does not find it economical to transport this wood to urban centers at present firewood prices, but converted to charcoal it is a profitable proposition.

Storage — Charcoal will keep indefinitely without deteriorating, even in an exposed situation, in contrast to firewood which will be destroyed in a few years. Charcoal can also be packaged in bags of convenient sizes to facilitate handling.

Energy efficient in use — This is an important feature of charcoal in the context of fuel-wood availability in Sri Lanka. The crucial fact is that a well designed stove is essential to burn charcoal (it cannot be burnt, like firewood, in an open hearth) and even a simple stove such as the CISIR developed model, has an efficiency of about 30%. Considering the fact that an open hearth (to burn firewood) has an efficiency of only 10% to 15%, use of charcoal amounts to a big saving of scarce fuelwood resources. The situation is complicated by the fact that during conversion of wood to charcoal in a kiln, 40% to 50% of the wood is consumed. Nevertheless, as the flow chart below illustrates, use of charcoal nearly doubles the amount of utilizable energy.



Therefore theoretically fuel wood requirements of the country can be nearly halved by switching over to charcoal. A more practical figure would be a 25% reduction.

Majority of the rural folk, who obtain firewood at no direct cost, will continue to use firewood whatever the benefits of charcoal. Mention must be made of the Lorena type improved wood burning stoves, such as the one being popularized by the Industrial Development Board, that have efficiencies of 15% to 20%. However the popularity of these have not caught on, either in Sri Lanka or in other South and South East Asian countries, probably because its bulky, has to be constructed *in situ* and requires a moderate investment (about Rs. 50/- in Sri Lanka). The CISIR designed charcoal stove costs Rs. 20.00, it is portable and occupies an area of one square foot. This is currently being marketed by the State Timber Corporation. The CISIR also has designs of improved wood burning stoves suitable for owner construction.

The use of charcoal has its negative features too. The main drawback is that its ignition time (ie. starting-up time) is about 15 minutes. This eliminates using the charcoal stove for a quick cup of tea. Secondly, heat regulation is not possible in stoves of low price such as the present CISIR model. A test group of over 50 households that used the stove for 5 to 6 months, found that these defects could be generally overcome by planning the sequence of dishes to be cooked and by the experience and skill of the operator. Advanced models of the stove that offer waste heat utilization and heat regulation are under study at the CISIR. These will, naturally, cost more than Rs. 20.00.

Future prospects

Popularity of charcoal will ultimately depend on the cost of using charcoal relative to other common fuels. An experimental study (Tables I and II) has shown that for domestic use charcoal is more economical than kerosene even at the present subsidised price of kerosene while charcoal cannot compete with fuel oil for industrial use.

TABLE I

Comparison of cost to cook average* meal. (All prices — January 1981).

Fuel	Time	Fuel consumed	Unit price	Total cost Rs.	Saving by using charcoal	Remarks
Charcoal 6% moisture	2 hr	490 g	Rs. 2.35/kg	1.15	——	No heat regulation Slow ignition No smoke or soot Compact size.
Kerosene	2 hr	481 ml	Rs. 3.93/1**	1.89	(+) 39%	Heat control, soot
Firewood 10% moisture	2 hr	2.5 kg	Rs. 0.37/kg	0.93	(—) 23%	Heat control, smoke, soot Needs constant attention.

**Rice (900g) meat (250g) and 2 vegetables (250g each)

*Subsidised price. Subsidy Rs. 1.84/l approx.

The significant fact that emerges from this exercise is that coconut shell charcoal is also cheaper to use than kerosene. Although wood charcoal exports were stopped recently, coconut shell charcoal continues to be exported at a price that does not correspond to its value as a fuel. While one kilogram of coconut shell charcoal is exported at Rs. 2.50, kerosene with an equivalent heat content costs Sri Lanka Rs. 5.21. In actual utilization the cost of producing 10,000 k/cals from coconut shell charcoal and kerosene is Rs. 11.19 and Rs. 14.49* respectively.

The present drive to popularize charcoal as a fuel for domestic use is spearheaded by the State Timber Corporation. This organization has undertaken the giant task of carbonizing the waste wood from the Mahaveli zone and marketing the product, without simply leaving the wood on the land either to be submerged by water or reduced to dust as in the past irrigation schemes. The effort is all the more commendable because the exercise is not profit motivated but designed to alleviate the energy crisis in the country.

The question now is what happens when the Mahaveli charcoal, expected to suffice for 8 to 10 years, is exhausted? Future requirements will have to be supplied from fuelwood plantations. These plantations of fast growing eucalypts and other species will have to be established immediately so that they can be harvested, at maturity, in 8 to 10 years. In addition CISIR is carrying out research on carbonization of rice husk and straw. The carbonized material will be used as a base to produce charcoal pellets and briquettes. By-products such as methanol and low heat value pyrolytic oils will also be available from this process.

These developments will ensure a steady supply of charcoal in the future. However it remains to be seen whether people will accept charcoal as an alternative fuel and thereby ease the pressure on kerosene oil and firewood, the former to reduce drain of valuable foreign exchange and the latter to conserve the forest cover and safeguard our environment.

TABLE II

Theoretical cost of heat from different fuels (All prices—January 1981.)

Fuel	Wood charcoal 6% moisture	Coconut shell charcoal 6% moisture	Firewood 10% moisture	Kerosene	Furnace oil (viscosity 500 sec) sp. gr. = 0.96
Domestic Utilization					
Heat value (k cals/kg)	7000	8000	4000	11,380	—
Price (Rs.)	2.35 kg	2.75/kg	0.37/kg	5.77*/l	—
Burning efficiency	30 %	30 %	10 %	35 %	—
Cost of producing 10,000 k cals	Rs. 11.19	Rs. 11.45	Rs. 9.25	Rs. 14.49	—
Industrial Utilization					
Heat value (k cal/kg)	7000	8000	4000	—	10,800
Price (Rs.)	2.00 kg	2.50/kg	0.37/kg	—	4.44/l
Burning efficiency	66 %	66 %	66 %	—	75%
Cost of producing 10,000 k cals	Rs. 4.33	Rs. 4.74	Rs. 1.40	—	Rs. 5.72

*Without subsidy.