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NO. 13

ENERGY RESOURCES IN SRI LANKA AND SUPPLY OPTIONS FOR THE FUTURE

By

J.W. HERATH

NATURAL RESOURCES, ENERGY AND SCIENCE AUTHORITY
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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the Natural Resources, Energy & Science Authority. The Journal of the National Science Council published by this Authority provides a medium for the publication of scientific research papers, and "Vidurava", the quarterly science bulletin contains scientific articles of a general nature which is of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Working Committee on Science Education Research of the Natural Resources, Energy & Science Authority decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and are not necessarily those of the Natural Resources, Energy & Science Authority.

I must thank the Working Committee on Science Education Research of the Natural Resources, Energy & Science

Authority, and in particular Prof. V. Basnayake who is the Hony. Director of the Working Committee for the work they have done to make this project a success.

R.P. Jayewardene
Director-General
05th March, 1985

FOREWORD

The subject of energy deserves particular attention in Sri Lanka in view of its essential nature for day to day living and in view of the large cost that the country has to bear to provide adequate amounts of commercial and domestic energy. Thus at this juncture it is both topical and meaningful that the author has been able to bring out this work on the subject of energy.

Except for a limited hydro-electric power potential, Sri Lanka has no known sources of other commercial forms of energy such as coal, oil or gas. Fuelwood forms a possible supplement. Thus in the present context a study of the subject of energy resources is of considerable importance.

Various forms of new and renewable sources of energy have been under active consideration. At the present moment the economic vaibility of the new energy forms do not permit large scale commercial use, except in particular limited applications.

In the present publication the author discusses in a simple and convenient form many aspects pertaining to energy. I congratulate the author for his efforts in writing this concise booklet and feel confident that it will be useful to a large sector of persons involved or interested in the field of energy.

Prof. K.K.Y.W. Perera
Secretary
Ministry of Power and Energy

PREFACE

This publication attempts to summarize the global energy scene and the alternative energy sources which would be available for use in the future including the energy situation in Sri Lanka. As for Sri Lanka the general conclusions drawn must be considered as tentative and preliminary. Future researches and studies by the Ceylon Electricity Board (CEB) may show that some revisions may be necessary to the data presented here, which has been gathered from various publications, organizations (including the CEB) and statements made by individuals. I wish to thank the persons who have permitted the reproduction of data from their published and unpublished reports.

It has been apparent that our advanced level students and undergraduates were in need of a text of this nature to cover broadly the subject of energy. At the same time it is felt that there are many working in the industry who would welcome a volume of this nature. Also in recent years there is much interest shown by the public on energy related problems. It is therefore believed that this group will find this volume of interest to them. Although the present volume is not intended to be an exhaustive treatment of the subject it does provide in a convenient form a summary which would be of use for all those interested in the subject.

I wish to express my great indebtedness to Mr. L.W. de Silva, General Manager, Ceylon Electricity Board for giving me the opportunity to discuss many of the topics in the present volume and his thoughts and work have contributed to some of the conclusions presented herein. Any ommissions or errors in the data presented are however solely those of the author.

My thanks are also due to my collegues attached to the Industrial Development Board, National Engineering Research and Development Centre, Ceylon Institute of Scientific and Industrial Research, Atomic Energy Authority, Ceylon Electricity Board, Forest Department, State Timber Corporation, Water Resources Board, Geological Survey Department, Meteorology Department, Ministry of Mahaweli Development, Natural Resources, Energy and Science Authority and National Aquatic Resources Agency who have helped me with data on various aspects of energy. By including the names of these organizations I do not wish to implicate them in any way with erroneous conclusions I may have come to or mistakes I may have made.

I should also like to record my sincere thanks to Mr. D.B.J. Ranatunga, General Manager and Head - Department of Solar Energy Utilization, NERD Centre, for reading the text in typescript and making numerous suggestions for its improvement, nearly all of which I was pleased to incorporate. My thanks are also due to Prof. K.K.Y.W. Perera, Chairman, Ceylon Electricity Board, for kindly

agreeing to write the foreward for this publication. Finally it is a pleasure to acknowledge the support and encouragement which came from NARESA for the publication of this volume.

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CHAPTER I

INTRODUCTION

Is there really an energy crisis ? As far as the ordinary man is concerned, probably not. Everyone however, is gradually beginning to feel the effects of the high prices now being paid for oil. Although at the moment this cannot be termed a crisis, an energy crisis is certainly coming in the not too distant future. The world is not running out of energy it is running out of oil. World oil production is expected to turn downward within the next 25 to 30 years, and severe shortages are likely to develop well before then.

The increasing price of oil has put many of the world's nations under severe stress. Since the early seventies many types of adjustments have been tried, for example, substituting other energy resources for oil, substituting other resources for energy, doing with less energy and accepting as a consequence lower material standards of living. These adjustments have been only partially successful. Looming ahead of us is another related problem, the large increase in population of the world. With population growth the demand for energy would become so large that production capacity will be strained and by the year 2000 demand will begin to outstrip supply capabilities. Beyond this point the real energy problem begins. The present population of the world which is estimated around 4.5 billion is expected to rise by more than 50 per cent over the next 20 years to 6.5 billion.

Of this total, 5 billion people are estimated to be in the developing countries. The present world energy demand level (total primary energy consumption) of 7 billion tons of oil equivalent is expected to rise according to estimates by the World Energy Conference, to about 12 -15 billion tons of oil equivalent by the year 2000.

To-day most industrialized countries are dependent on vast quantities of coal and oil to maintain their industrial progress; the industrialized world now operates on a two-fuel' economy. In time the existing sources of power will be hard pressed to meet the increasing demands on all sides and other forms of power production have to be utilized. This trend has been particularly marked in countries that are not endowed with indigenous sources of coal or oil. Although these other sources may make significant contributions to particular fuel economies their overall contribution to the world's energy economy is small and often insignificant. With the increasing price of conventional fuel considerable attention is now being paid to the discovery and development of new sources of energy. The desire then is to find alternatives to the 'big two' (coal and oil).

In the long run, the world will have to rely upon renewable, durable and virtually infinite energy supplies. Assume for a moment that by the end of the next 50 years we had not developed to any significant degree the many alternative energy sources now open to us. With oil and gas resources being gradually exhausted, we would have to first depend on nuclear power and coal to supply most of our energy needs. The message is therefore clear. Unless we move immediately to promote the efficient use of energy and develop and harness alternative forms of energy, we are bound to face serious problems.

The present bulletin attempts to give a brief account of the energy resources of the world, the alternative energy sources available as options for the future and the energy scene in Sri Lanka including efforts made by the State to develop alternative sources of energy. The author does not claim credit for the information included in this study. Such information is based on available technical literature, brochures or statements by manufacturers and on direct contacts and discussions held in specialized institutions when the writer was attached to the Commonwealth Secretariat London. The bulletin is not intented to be an exhaustive treatment of the subject. It only provides in a convenient form a summary which would be of value mainly to students and to those interested in the subject of energy in general.

CHAPTER 2

CONVENTIONAL ENERGY RESOURCES

GENERAL STATEMENT

The value of a fuel lies in its calorific value, that is, in the number of British Thermal Units (Btus) liberated by the combustion of one pound of that fuel. (The Btu is the quantity of heat required to raise the temperature of one pound of water 1°F). Pure carbon has a calorific value of 14,137 Btus and hydrogen a value of 61,493 Btus. The higher the proportion of hydrogen a fuel contains the better it will burn. The ideal fuel would therefore be hydrogen. The two principal combustible elements common to wood, coal and petroleum are carbon and hydrogen. The majority of fuels come directly or indirectly from carbohydrates. In this sense we owe most of our fuels to the sun.

The sun is a source of energy (radiant energy). We see it as heat and light. Plants use it to grow, starting the food chain which eventually provides man with muscular energy. Coal, oil and gas were originally living matter and required the sun's energy. Water power also involves the sun's energy. The sun makes the water evaporate and clouds of water vapour fall as rain. Flowing water was the earliest of the natural sources of energy to be harnessed for providing power. Even winds originate from uneven heating of the earth's atmosphere by the sun. Most fuels are really 'stored sunlight', because the plants needed the sun's energy to grow and the animals needed the plants as food. When we burn wood or alcohol (both extracted from living plants) we are really recovering recent solar energy. When we burn coal, oil or gas we are redistributing ancient solar energy. Coal, petroleum, and natural gas are often called fossil or hydrocarbon fuels.

The main sources of energy currently consumed in most countries include wood, coal, petroleum, natural gas and hydropower. On a global scale our total dependence over the last half century has been on the above fuels. Nuclear power (on a commercial scale) which came into operation around 1956 is perhaps the most immediately available new source of energy.

CONVENTIONAL ENERGY SOURCES

1. FUEL WOOD

In many developing countries rural energy still comes from traditional non-commercial energy sources - human muscle power, firewood and in some areas animal traction. Until about 100 years ago fuelwood was the major source of energy all over the world. At present its role in the energy economy of the developed nations is small. It remains however, a major source of energy for many of the world's less developed countries. It has been estimated that fuel wood supplies about one-fourth of the total energy consumed in developing countries as opposed to about one percent in the industrialized nations. In some developing countries especially in rural areas over 80 per cent of all energy used may be in the form of firewood. It is also unlikely that rural Asia will switch to an energy source other than fuelwood for many more years to come.

Forests could quite possibly be a self-generating source, if properly managed. There has been a historical tendency to over-exploit them at too rapid a rate. Although trees are a renewable energy source, population growth seems to outstrip tree growth and a progressive forest deterioration ensues. Except for a few countries the resource is being harvested more rapidly than it is being propagated and this can have serious ecological and social consequences.

Large scale removal of forest cover usually leads to rapid water run-off, soil erosion, silting and flooding in rainy seasons. Down stream flows in dry weather are also reduced with its impact on agricultural production. Also, when deforestation takes place the land loses ground cover, its capacity to retain rain water declines, and the water table beneath such land falls dramatically. Wells must then be sunk to great depths. Problems of deforestation are becoming visible all over south-east Asia as well as in other developing countries. With the probable continued dependence of rural areas on this energy source, attention has been focussed in recent years on ways to ensure fuelwood supplies on a "Sustainable" basis, through the development of areas earmarked for this purpose.

2. PEAT, LINGNITE AND COAL

Peat is used as a fuel in many countries. Peat formations start with the death and partial decay of plants boardering pond or swamp. As the vegetation grows, dies and decays, year after year, an accumulation of peat forms. Drying of peat is one of the great problems of peat working. Much of the technological developments on peat throughout the world are related to methods of preparing it for ultimate consumption. Much effort has been devoted by such countries as Ireland, USSR, Finland and Sweden on methods and processes of utilizing peat as a fuel. Peat is in short a mediocre fuel and has a calorific value in the range 7,200 - 10,800 Btus. It is used in compressed form for industrial heating. Peat is also used as a manure and on distillation it yields coke, tar, ammonia and fuel gases.

Lignite is essentially a low-rank coal with a calorific value between 10,800 and 12,600 Btus. It is a poor fuel like peat, and is utilized for industrial purposes after drying and briquetting. Its calorific value is slightly higher than that of peat. Apart from its use for industrial heating, on distillation it yields gas, coke, synthetic gasoline, bitumen, ammonia and numerous pharmaceutical products. The main lignite deposits are found in the United States, Russia, Germany, Czechoslovakia, France and England.

Coal is the largest developed energy source and the main industrial nations are those rich in coal. Coal is formed from vegetable material and is classified into ranks according to the degree of alteration from vegetation to fixed carbon. Peat is the first stage and is not considered a coal. There are three main ranks of coal, lignite, bituminous and anthracite. All bituminous coal was at one time lignite, and anthracite has also passed through a lignite stage. In their incipient stages all coals were peat. Anthracite is the hardest of all coals. It is clean to handle and has a calorific value of 14,000 - 16,000 Btus. Bituminous coal with a calorific value of 12,000 - 15,000 Btus is the ideal coking and gas coal.

Coking coals may yield from 50 to 80 per cent coke. Coke which is specially made for smelting iron ore is prepared in a closed vessel in the absence of air (reducing atmosphere) thus preserving the full calorific value of the products. The coal when molten is made to solidify into hard material of fixed carbon. The crude gas given off from the ovens is purified for consumer use. In round figures one ton of coal yields 682 kg. of coke (mainly used in blast furnaces), 90 kg. of tar, 5 kg. of benzol (distilled to give gasoline and napthalene) 3 kg. of ammonia (used in the fertilizer industry) and 340 cubic metres of gas (used for heating and illuminating purposes).

Coal is probably the world's leading fuel. It is burned to yield heat for many purposes - to generate electric power, to manufacture liquid fuel (oil-from coal), in steam turbines, to provide mechanical power in ships and locomotives and to make combustible gases, tar and its numerous derivatives. In England and Wales where over 90 per cent of the power supply comes from steam generating stations, coal accounts for 85 per cent of the fuel used in the stations, the balance being supplied by oil and uranium. World production of coal is now in the region of 3,600 million tons per annum and the main producing countries include USA, USSR, China, Poland, Germany (FR), U.K. India, South Africa and Australia (See Table I).

TABLE 1
OUT PUT OF COAL IN SELECTED PRODUCING COUNTRIES

Millions of Tons - (1979 - 1980)
Provisional

Country	1979	1980
USSR	725	715
US	740	830
China	630	610
UK	130	127
Poland	213	193
India	100	110
Australia	90	100
South Africa	100	115
Canada	37	36
Germany (FR)	85	88

World total not available.
Estimated output figure around 3,600 million tons per annum.
Mining Annual Review 1981.

World resources of coal (all ranks of coal - anthracite, bituminous, lignite) are estimated at approximately 12,560 billion short tons - half the resources available are in the USSR. The annual rate of production has for some years been stabilized at around 3,600 million tons. As the present world wide glut of oil is unlikely to last for many more years, large amounts of coal would be used in the near future in the event of a serious shortage of oil. However, the world reserves (888 billion tons) are sufficient for many hundreds of years (See Table II). Coal will in the near future, doubtless, be tapped as a transitional energy source till an alternative to petroleum is found. But coal is distributed even less equitably than oil, very few developing countries have coal deposits. With oil reserves being exhausted it is reasonable to assume that a new coal age is in sight.

TABLE II

WORLD COAL RESERVES

(Million short tons)

REGIONS	RESERVES	OTHER RESOURCES	TOTAL
North America	437,300	3,651,000	4,088,300
South America	1,750	34,530	36,300
Europe	380,190	6,591,635	6,971,825
Africa	3,530	61,359	64,889
Asia	62,600	1,154,686	1,217,286
Oceania	3,040	217,060	220,100
World Total	888,410	11,710,290	12,589,700

Estimated by World Survey Conference and US Geological Survey 1974. Mineral Facts and Problems. Bulletin 667. Bureau of Mines US 1975.

3. PETROLEUM AND NATURAL GAS

Petroleum is no recent discovery. In the eighteenth century when the history of American petroleum began the 'Black oil' was collected from the surface of marshes and sold in bottles. The colonists at the time used the petroleum to grease the axels of their wagons, to heal the wounds of their horses and to treat their own rheumatism and injuries. Petroleum was, in short, a panacea for all ills. In 1840 a chemist from Yale University distilled the contents of a bottle of the 'Black oil' and the extract he obtained was light and inflamable. This discovery came at an opportune moment. Whale oil which had previously been used for lighting was becoming scarce and petroleum oil lamps were developed. By 1859 existing sources were no longer sufficient to meet the increasing demands for lighting and therapeutic applications. It was Edwin Drake who sank the first bore hole in search of petroleum in June 1859. By the greatest of chances he happened to pierce the ground at the correct place, and on the 27th August, 1859 oil began to flow (10 barrels a day). In 1862 production exceeded demand and the price of petroleum collapsed.

The origin of petroleum is connected with enormous quantities of minute marine life buried in shallow ocean bottoms. Slow decomposition of this material is believed to result in the formation of tiny droplets of oil. Increasing compaction of sediments forces the droplets out into porus earth strata like sandstone which is a good reservoir for accumulation of oil. Useful quantities are formed when a trap structure exists for holding the migrating oil within the reservoir. In its world distribution, oil is quite irregular and unequal. The major petroleum deposits of the world are found in sedimentary basins and troughs, generally in the vicinity of land locked seas occupying intercontinental depressions in the earths crust. Drilling for petroleum is a costly operation. The crude oil emerges from petroleum wells as a thick viscous, and sometimes evil-smelling brown or dark green liquid. The crude oil so obtained has to be refined to produce fuel and a variety of other petroleum products.

Chemically, petroleum is a mixture of compounds of carbon and hydrogen. The main hydrocarbons in oils are paraffines, napthenes or aromatic groups or complexes of them. Other substances present include sulphur, oxygen and nitrogen, including numerous miscellaneous substances. Of the physical properties the most referred to is the density or specific gravity. The density of a substance is the weight of a given volume (pounds per cubic foot). The specific gravity is another way of expressing the same thing without specifying a unit of measure. It is the ratio of the weight of a given volume of any given substance and the weight of an equal volume of pure water at a particular temperature and pressure. The price of crude oil is generally based on specific gravity.

World crude oil production in 1977 was around 62 million barrels per day (b/d) or 22 billion barrels per annum. The 13 members of the Organization of Petroleum Producing Countries (OPEC) produced 31.0 million b/d (1 barrel = 42 US gals.) thereby supplying 50.4 per cent of total world requirements. The Soviet Union ranked first (11 million b/d), United States second (9.9 million b/d) and Saudi Arabia third (9 million b/d) amongst world crude oil producers. Together these three countries produced half the total world production (See Table 111). World estimated proved reserves of crude petroleum amount to 716 billion barrels and the Middle East countries are known to have over one-half of this reserve (See Table 1V).

Mineral deposits are considered an exhaustible resource. This also applies to crude oil reserves. It is well known that the crude oil reserves of the world are gradually being exhausted and world oil production is expected to turn downward within the next 25 to 30 years. However, new deposits are being discovered and experience has shown that as our geological understanding and our exploration techniques have improved so has the extent of new discoveries been enlarged. At present serious consideration is being given by most countries to oil exploration in new prospective areas, and large sums of money are being invested in this area of activity. In recent years oil technology developments have contributed to new field discoveries, increased recovery, expanded refining capabilities and improved transportation.

Up to recent years heavy crude and tar sand deposits were considered an uneconomic source of gasoline and petrochemicals. Improved technology is now available for their recovery and processing. A number of countries including OPEC are now mixing heavy crude oil with the light varieties for refining. Heavy crude unlike the light crudes are difficult to pump out from wells. Steam has to be injected underground to heat and dissolve the material for pumping. The sands are composed of solids which are usually strip mined and treated with chemicals and boiling water to extract the oil. Madagascar has one of the largest tar sand deposits of the world. Other countries with very large reserves include Canada, USA and Venuzuela. It is believed that these countries alone have nearly three times the known reserves of today's principal light crude suppliers.

Natural gas occurs in association with petroleum as also in gas fields and a commercial natural gas field is rich in methane the most stable of the petroleum hydrocarbons. The USA, USSR, Canada and Netherlands are rich in natural gas reserves and accounted for four-fifths of world marketed production. The energy demands of the household and commercial sector will in the future be met increasingly by natural gas as the prime fuel source.

TABLE III
WORLD CRUDE OIL PRODUCTION
Million (b/d) - 1977

1. Industrialized Countries	
United States	9,851
Canada	1,607
Norway	280
U.K.	774
Australia	430
Total	13,333
2. Developing Countries	
Mexico	1,004
Argentina	432
Egypt	417
Malaysia	393
Oman	340
Others	1,522
Total	4,108
3. OPEC	
Algeria	1,140
Ecuador	179
Gabon	225
Indonesia	1,687
Iran	5,700
Iraq	2,265
Kuwait	1,868
Libiya	2,075
Nigeria	2,103
Qatar	438
Saudi Arabia	9,197
United Arab Emirates	2,013
Venezuela	2,235
Total	31,125

4. Centrally Planned Economies

USSR	10,995
China	1,785
Others	404
Total	13,184

WORLD TOTAL

1977 -	62 Million	(b/d)
1979 -	65 Million	(b/d)
1980 -	52 Million	(b/d)
1981	48 Million	(b.d)

258 gals crude oil = 1 ton
42 gals US = 1 barrel

(b/d) - barrels a day

Mining Annual Review 1978 - 1981 - 1982
Mining Journal London

4. HYDRO-ELECTRIC POWER

Over the centuries dams were designed and built to ensure a systematic distribution of river water, the water was used as the driving force for mills. The falling water set in motion the water-wheel which turned the millstones for grinding; they also became the source of power for varied industries. The extraordinary growth of hydro-electric power came at the beginning of this century. Irrigation and the production of electricity are but two of the purposes of dams, that of navigation may also be achieved.

TABLE IV
WORLD CRUDE PETROLEUM RESERVES AS OF JANUARY 1975

(Billion Barrels)

Western Hemisphere		
	United States	35.3
	Canada	9.4
	Mexico	13.6
	Others	27.0
	Total	85.3
Eastern Hemisphere		
	Middle East	403.9
	Africa	68.3
	Others	158.2
	Total	630.4
World Total		715.7

Oil and Gas Journal
V72, No. 52, 1974. pp. 108 - 109.

The harnessing of water power involves the construction of a dam across a river. The most favourable site for the construction of a dam is a flat-bottomed valley with steep sides narrowing so abruptly that only a few hundred feet or less separate the two banks. The purpose of the supply reservoir is to store the water in order to regulate the flow and the generation of electricity and also to create a high level in the reservoir so that the ensuing drop will create a suitable head for the operation of the turbines which are combined with a generator which provides the electric current. The power house is situated at the base of the dam. Electricity is not a source but a form of energy derived from available sources. The use of electricity in very large quantities is strikingly associated with the highly industrialized countries of the world. The capacity of water reservoirs built for hydropower generation is assessed in terms of kilowatt hours (kwh).

From the economic point of view modern industry has created a demand for large amounts of cheap electricity which can sometimes be satisfied more readily by water power than by any other means. This applies only to countries with the requisite physical characteristics the most obvious being adequate rainfall. Equally important are pronounced topographical features which provides high level sites where water can be collected and stored. Countries with heavy rainfall and mountainous areas are very well placed for hydro-electric development. With the uncertainty that prevails as to future supplies of oil more hydro-electric sites are being brought into operation by countries with the required water power potential.

SUMMARY

The foreseeable depletion of the fossil sources of primary energy (oil, coal and gas), the rising energy consumption in the industrialized countries with growing industrialization in the developing countries together with the growth of the world's population compels us to conserve our present sources of energy and use them sparingly. At the same time new technologies for energy use have to be developed and new sources of energy have to be tapped. The world is not running out of energy - it is running out of oil. The main sources of energy currently consumed in most countries include wood, coal, petroleum, natural gas and hydropower. Our total dependence over the last half century has been on the above energy sources. The worlds first commercial scale nuclear power station at Calder Hall, Great Britain, came into operation in October 1956. Nuclear power is perhaps the most immediately available new source of energy. World oil production is expected to turn downward within the next 3 decades and with the increasing price of conventional fuel it is essential that we move immediately to develop alternative forms of energy for use where possible.

CHAPTER 3

ALTERNATIVE SOURCES OF ENERGY

GENERAL STATEMENT:

Mineral resources including petroleum are for all practical purposes non-renewable. As a generalisation it may be said that the richer deposits of the world have been or are being exhausted and the future needs must therefore come from deposits of lower grade. We are now faced with exploiting the less rich and less accessible sources as far as mineral resources are concerned. Over the years the brunt of the demand for power has fallen upon coal and oil. Will these two fuels be able to bear the load ? As far as coal is considered the world coal reserves are sufficient for many hundreds of years. At present rates of consumption, and allowing for projected increases it is believed that world oil production is expected to turn downward resulting in severe shortages after the turn of the century.

As a result of the recognition that the sources of energy presently dominating will no longer suffice to meet the world wide requirement even in the foreseeable future, the development of new sources of energy for a variety of domestic and industrial requirements has for sometime been one of the main goals of applied research. If therefore, one or more of the possible future sources of power proves a cheaper method of supplying energy than coal or oil, their contribution could be significant. A study of the available sources of power makes it clear that we have scarcely begun to tap the vast potential power sources of our planet. These sources include nuclear, solar and wind power, biomass, tidal energy, thermal energy of water, hydro-electrical power, geothermal energy, hydrogen and other sources which are being currently examined.

1. NUCLEAR POWER

Perhaps the most immediately available new source of energy is nuclear energy (atomic energy). This energy is derived from the central core or nucleus of the atom. The principal raw material for nuclear power generation is uranium (U), because under certain conditions its atoms could be made to split up and release enormus amounts of energy. Nuclear energy is released during a nuclear reaction where mass has been converted to energy. Einstein's theory of relativity explains how mass and energy are really two different forms of the same thing. At the centre of every atom lies its core or nucleus which is positively charged. The nucleus is made up of particles called protons which possess the positive charge and particles called neutrons which have the same mass as the protons but have no charge at all. Revolving around the nucleus are tiny particles called electrons which are negatively charged. When the nucleus is broken down there is a change in mass which appears as energy in the form of heat and radiation. This is the energy of motion and is released because the particles in the nucleus move at tremendously high speeds when the atom is split.

Uranium is one of the earth's most valuable naturally occurring elements. Its great value is due to the fact that it is radioactive. Uranium was first discovered in the mineral pitchblende in Germany in 1789, and it derives its name from the planet Uranus. The common uranium minerals are Uraninite (Pitchblende) Tobernite, Autunite, Uranophane, Carnotite, Fergusonite, Davidite and Samarskite. Uranium minerals contain three types of uranium atom, each with different atomic weight (238 - 235 - 234). These atoms called isotopes (atoms of the same element but of different masses) occur in constant proportions - U 238 (99.285 per cent), U 235 (0.71 per cent) and U 234 (0.005 per cent). It is the isotope uranium 235 which can produce a nuclear chain reaction. It is used in nuclear reactors and nuclear weapons.

All uranium minerals are radioactive. Radioactivity was first discovered by Henri Becquerel in Paris in 1896. Atoms of radioactive elements disintegrate and they change or decay to atoms of other elements. Atoms of uranium decay eventually to atoms of lead. The time that it takes for half of the atoms to change or decay to atoms of another element is called the half-life period. This ranges from a fraction of a second for some radioactive elements to many millions of years for others. The half-life of U 235 is 7.13 x 10^8 years and natural uranium is only mildly radioactive.

When uranium disintegrates to form other radioactive elements, radiation is given out at each stage. Alpha and beta particles and gamma rays which are detectable are measured in energy units of million electron volts. Gamma rays have a longer range and a greater penetrating power and this property is widely used in prospecting for uranium using Geiger-Muller counters and scintillometers. The Gamma-ray spectrometer, generally mounted in cars and aircraft is widely used in exploration programmes for uranium. Air borne radiometric surveys provide initial evaluation of large areas. Systematic geochemical sampling of soils and waters may also provide guides to favourable uranium areas. These surveys are followed by exploratory drilling programmes.

Reactions involving the nuclei of atoms which may release useful energy are of two types; fission and fusion. In the fission process a large nucleus is induced to split into two or more smaller nuclei; in the fusion process the particles of two light nuclei are rearranged to form a larger nucleus. So far all nuclear power stations use the fission process for nuclear power generation. The fissioning of one pound of uranium (U 235) can produce as much heat as 1500 tons of coal or can produce nearly 10 million units (kwh) of energy through a sustained nuclear chain reaction whereas the combustion of one pound of oil yields only 5.7 units (kwh) of energy.

When an atomic bomb explodes, a vast amount of energy is released in a fraction of a second. The energy that was locked up in the nuclei of the uranium atom is released when the nuclei are split up. Particles from the nucleus, the neutrons are also emitted. These neutrons are captured by more uranium nuclei which then split up releasing more neutrons. This process keeps on repeating itself until the whole mass of uranium is consumed. In this chain reaction a vast amount of energy is created. The atomic explosion is an example of an uncontrolled fission reaction with all the energy released in as short a time as possible. To operate a nuclear power station a steady source of energy is needed. This may be obtained from a controlled fission reaction in which the uranium fuel must be consumed slowly. This process is carried out in a nuclear reactor or pile. The neutrons emitted in fission are fast and must be slowed down as soon as possible mainly to enable them to be captured by uranium 235 in order to produce further fission. This process is carried out in a medium called a moderator. Water, heavy water and graphite are used as moderators. Materials capable of sustaining fission chain reactions are said to be fissile.

Fissile radioactive material (U 235) is stored in small quantities of less than a certain amount known as the critical mass. Below the critical mass neutrons escape from the surface of the body of the material so there are not sufficient moving within the material to initiate a chain reaction. The fuel is placed in the reactor as plates, single rods or clusters of rods. The control of a reactor is exercised by use of rods made of neutron absorbing materials (boron or cadmium). These are inserted or withdrawn from the reactors as necessary. When the control rods are inserted into the reactor core, they absorb neutrons which would normally cause fission and then the chain reaction is inhibited. Withdrawal of rods leaves more neutrons available to cause fission, so the chain reaction increases in intensity. The heat liberated in the fission process is removed by a circulating coolant, the function of which is to transfer the heat from the reactor to the boilers or heat exchangers where the steam that drives the turbo-generator is produced. There are at present many versions of reactor design. The selection of any given reactor will depend on the many problems that must be considered before construction begins. Most of the plant used in a nuclear power station is similar to that found in a conventional power station. The major difference lies in the method of heat production.

The initial marketable product from ore is the U_3O_8 mill concentrate or yellow cake. Four oxides of uranium are known - UO, UO_2, UO_3, and U_3O_8. Most mill concentrates contain an average of 80 - 85 per cent U_3O_8. The U_3O_8 concentrate is refined to remove impurities and is converted to a hexafluoride product UF_6 for enrichment services. Competitive U_3O_8 to UF_6 conversion services are offered by companies in Canada, UK, France and the USSR. Enriched UF_6 is converted to a fuel form for use in the manufacture of nuclear fuel elements. Pelletized UO_2 is the most common fuel form. Reactors using natural uranium (without enrichment) have also been developed.

Uranium isotopes can also be produced artifically. If a U 238 nucleus captures a neutron, it is converted by radioactive decay to plutonium (used in atomic bombs) an artifical element which, like U 235 can sustain a chain reaction. It is produced as part of nuclear waste in reactors. Plutonium can be separated from nuclear waste and could be mixed with fissionable uranium and recycled back into the reactor as a mixed fuel or it can be used in pure form in what are known as fast breeder reactors. The fissionable material U 233 is formed by the neutron bombardment of thorium (Th 232). It is believed that this material could also be used in future breeder reactors. The use of thorium as a nuclear fuel is at present uncertain, thorite ($Th SiO_4$), thorianite (ThO_2) and monazite (LaCe) PO_4 are the principal thorium bearing minerals and monazite has been the principal source of thorium. The production of fissionable material from fertile material is known as breeding and a breeder reactor is one that produces more fissionable material than it consumes. Breeder reactors could increase approximately 60 times the useful energy contained in uranium. For this reason the development of breeder reactors is boosted by many industrialized countries at tremendous financial expenditure.

Most of the world's known resources and anticipated resources of uranium are in four countries, the United States, Canada, Australia and South Africa. It is estimated that world reserves of uranium are sufficient to cover the needs of nuclear power programmes up to about the year 2030. About 70 per cent of the world's identified resources are in sandstone type deposits and Precambrian metasedimentary conglomerates. Uranium demand for nuclear fuel use has gathered momentum in recent years, as the industrialized nations and developing countries are planning nuclear power programmes for future energy needs. Exploration programmes to locate new uranium deposits are in progress in most countries. Few people are aware of how extensive the spread of nuclear power has become across the world since the world's first commercial nuclear power plant (Calder Hall in Great

Britain) supplied electricity to the National grid in 1956. In some European countries (France, Sweden and Belgium) over a third of the electricity is already generated by nuclear power. In 1979 there were nearly 224 nuclear reactors installed by 22 nations with a total capacity of 109,000 MWe (See Table V). Taking into consideration the developing nations (in 1979) there were 7 nations operating nuclear power plants whose combined output was 4000 Mwe. By 1985 it is believed that this will increase to 17 countries and 54 power reactors with a combined output of 30,000 MWe (See table VI).

Nuclear fuel reprocessing is considered the weak link in the fuel cycle chain in a nuclear reactor. Approximately one-third to one-fourth of the reactor fuel is removed and replaced with new fuel bundles on an annual basis. Nuclear reactors are the most significant sources of radioactive wastes. The wastes are collected, treated and disposed of safely by permanent burial or other means. It seems to be a basic principle that a country producing radioactive waste will first have to consider the potential for disposing the waste in its own territory. The objective of waste disposal is to protect the present and future population from potential hazards posed by wastes produced by the use of nuclear energy. With today's technology the most feasible option to dispose of nuclear waste is to place them safely underground in large mined repositories. However, concerned segments of society still demand the application of the best and safest disposal technology. It is believed that strategies which are vastly safer than existing proposals can indeed be achieved. One such method mentioned involves the disposal of waste in deep widely dispersed drill holes placed in favourable geological environments.

Just as the fission of heavy atomic nuclei releases energy, so does the fusion of light atomic nuclei. The fusion of hydrogen is the Sun's chief source of energy. Fusion or thermonuclear reactions are a promising source of power. Deuterium, an isotope of hydrogen is used as the starting point for man made nuclear fusions, since it is easier to fuse than ordinary hydrogen. The future for fusion power is not so clear-cut since at the moment this possible power source is only in the fundamental experimental stage. However, as the raw material for this method of nuclear power is heavy hydrogen or deuterium, which form one part in five thousand of all the virtually inexhaustible hydrogen in the water of the oceans, the prospect is one of unlimited power supply for the future. Nuclear fusion may therefore open up a source of energy as rich as breeder reactors for electricity generation.

TABLE V

NUCLEAR POWER REACTORS IN OPERATION AS OF 1ST JANUARY, 1979

Country	No of Reactors	Capacity (MWe net)
U.S.A.	68	49,659
Canada	10	4,755
Belgium	4	1,676
Finland	2	1,080
France	14	6,353
Germany, Federal Republic of	13	6,070
Italy	4	1,382
Netherlands	2	499
Spain	3	1,073
Sweden	6	3,700
Switzerland	3	1,006
U.K.	33	6,982
Japan	19	11,009
Argentina	1	345
India	3	602
Korea	1	564
Pakistan	1	126
U.S.S.R.	28	8,616
Bulgaria	2	816
Czechoslovakia	2	110
Germany, Democratic Republic of	4	1,287
Taiwan	2	1,208
Total	224	108,922

IAEA - Nuclear Power Development, International Colloquium on Science - ACAST. Vienna August 1979.

TABLE VI

REACTOR UNITS AND NUCLEAR ELECTRICITY CAPACITY (MWe) IN DEVELOPING COUNTRIES

Country*	Operating in 1978	Planned for Operation by 1985
Argentina	1 (345)	2 (945)
Bulgaria	3 (1260)	4 (1680)
Brazil	-	3 (3115)
Czechoslovakia	2 (490)	9 (2970)
Cuba	-	2 (880)
Hungary	-	3 (1225)
India	3 (600)	8 (1690)
Korea, Republic of	1 (560)	4 (2700)
Mexico	-	2 (1310)
Philippines	-	1 (620)
Pakistan	1 (125)	1 (125)
Poland	-	1 (410)
Rumania	-	1 (440)
Taiwan	1 (600)	5 (4000)
Turkey	-	1 (620)
Yugoslavia	-	1 (630)
Iran	-	6 (6580)
Total	12(3980)	54(29940)

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* Some additional countries involved in feasibility studies or bidding: Bangladesh, Chile, Egypt, Greece, Indonesia, Libya and Thailand.

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2. SOLAR ENERGY

The sun is a star around which the earth and other planets revolve. It is a mass of hot gases more than a million times as large as the earth and over 300,000 times as heavy. It is about 93 million miles away. Light from it takes around 8 1/2 minutes to reach earth. The sun's heat and light is produced when hydrogen atoms inside it join together to form atoms of helium. The temperature at the centre of the sun has been estimated to be about 20 million degrees centigrade, and at its surface the temperature is 6000 C^o. The sun is a source of energy (radient energy). As the sun's energy is spread over large areas with low density, it becomes costly to collect this energy. Moreover, it is not available at night when it is most needed. Recent research and development work has however, revealed that costs have decreased in the area of solar energy use as an alternative energy source.

Few people realise that the use of solar energy is nothing new. By 1910 in Los Angelos hundreds of solar water heaters were in daily use. Earlier in 1870 it is believed that solar powered printing presses were in use in some parts of America. The first recorded use of solar energy for desalination was as far back as 1850 which was in operation in Chile. The use of solar energy is once again being developed and the pace can be expected to accelerate rapidly over the coming decade. Current studies into the possible uses of solar energy are being undertaken by a number of countries and the sunnier areas of the world will be the greatest beneficiaries. It is ironic that the very countries whose actions have brought about our renewed interest in solar energy (OPEC Members) will be some of the principal beneficiaries of the development work in solar energy now under way.

Of all the applications of solar energy, the use of flat plate collectors in heating is the most practical. From 1960 onwards, flat-plate collectors have had the biggest share in research and development. A flat-plate collector normally consists of an absorber (a sheet of material which absorbs solar heat and conducts it to the transfer medium), which is made of blackened metal (usually copper) and a grid of pipes soldered to the absorber. This assembly is placed in a box with insulation at the back of the absorber and one or two transparent covers at the top to allow sunlight to pass, which heats air or water circulating through the grid of pipes soldered to the absorber. The heated material is then used to perform various functions. Systems with concentrating collectors have also been developed and higher working temperatures can be reached than those attainable with flat-plate collectors. These collectors track the continuously changing position of the sun.

Some methods of utilizing solar energy have reached a stage of development when they can compete economically with methods of using conventional energy sources. As developing countries are often situated in sunny regions it is in their own interest that they should develop the utilization of solar energy which is free, inexhaustible and non-polluting. This energy could be converted to mechanical, electrical or chemical energy to be used in various fields, such as the production of electricity, desalination of water, water for irrigation, cooking, food preservation by means of refrigeration, drying, space heating and air conditioning.

2.1 Solar Water Heaters

Solar water heaters are based on the common phenomenon that cold water in a container exposed to the sun undergoes a rise in temperature. In its modern form the solar water heater is basically a flat-plate collector (mounted on a roof) and an insulated storage tank. The collector absorbs solar radiation and by transfer of the resulting heat to water circulating through the tubing, hot water is supplied to the storage tank. A collector area of 30 - 40 square feet in combination with a tank of 50 - 100 gals. capacity can provide 50 - 80 gals. of hot water at 60°C per average sunny day in a favourable climate, CISIR - Australia (1974).

The technology of solar water heating is now accepted as reliable and well proven. Commercial firms in a number of countries are now manufacturing and marketing solar water heaters. They are extensively used in Japan, U.S.A. Isreal and Australia and are being introduced for use by a number of other countries. Applications include domestic water heating, swimming pool heating and pre-heating of industrial process water.

2.2 Solar Space Heaters

The technology of solar space heating where water is the medium is essentially an extension of the technology employed in solar water heating. Any solar heating system however must include a conventional heating system. A fuel of some sort must therefore be available. This applies specially to temperate climatic regions where the greatest demand for heat will occur during periods of no sunshine. It is clear therefore that a major design problem is to achieve the most economical combination of solar energy and conventional fuels in the space heating system. Two modes of heating have been employed a passive and active system.

In one of the passive systems, solar radiation heats the absorbing surface, the dark outer surface of the wall which is oriented towards the south (in the northern hemisphere). The distance between the absorbing surface and the double sheet glass constitutes a duct in which air warms up and rises and then enters the space to be heated through an aperature in the upper part of the wall. As the warm air heats the space, it cools, descends and returns to the duct by an aperature at the bottom of the wall. This system is being used in the south of France, for space heating purposes.

In an active system water is heated in flat solar collectors and is circulated through a storage tank into radiators in the space to be heated. An auxiliary source of heat may be used. Systems using air as the heat-transfer medium between the collector and a storage bin containing small rocks have also been used successfully. Solar heat is stored in the rocks and recovered when needed by passage of air over the rock and hence to the rooms.

Solar heating systems have been built and operated for many years (USA, Japan and France). The design principles are fairly well established. As fuel costs rise solar space heating will undergo rapid commercial development.

2.3 Solar Stills and Desalination

Desalination of sea water or brackish water can be achieved by solar stills. The principle of solar water desalination is simple. A layer of salt water in a container is covered by sloping sheet glass. The bottom of the still is painted black as it absorbs a large amount of the solar radiation and heats the water which begins to evaporate. The vapour reaches the cooler underside transparent glass cover on which it begins to condense. A system for collecting the condensed water is provided. The idea was applied in 1892 at Las Salinas, Chile. Solar distillation is now used to supply domestic needs in isolated areas in Australia, Chile, Greece, Haiti, India, Mexico, Pakistan and other countries. The still when constructed also serves as a rainfall catchment surface. Solar distillation now appears suited to water requirements on a small scale (less than 50,000 gals. per day). A good still should produce about 25 gals. of water per square foot of evaporating surface per year, Talbert et.al. (1970).

2.4 Solar Salt Production

Solar evaporation of sea water or brines has been a traditional method of obtaining salt. It is used in both the developing and industrialized nations. Modern developments have been concerned with improved pond construction and salt harvesting methods.

2.5 Solar Drying

Of all the direct uses of solar enegy, sun drying of crops is perhaps the most ancient and widespread. The customary techniqüe involves spreading the material to be dried in a thin layer on the ground to expose it to the sun. In recent years attempts have been made to protect products from rainfall, dust and insects. A number of designs of solar driers have been developed. The term 'Solar Drying' also has come to mean the process whereby products are dried not by direct exposure to the sun - but by means of solar-heated air in more protected surroundings. Work is also being carried out on the use of solar timber kilns. The idea is to increase the drying rate of timber as compared with the traditional air-drying method in open yard stacks or in open-sided sheds. Experimental solar kilns have been set up in India, USA, Philippines, Uganda, Tanzania, Ghana, Madagascar, Sri Lanka and in other countries.

2.6 Solar Refrigeration and Air Conditioning

When solar radiation is used as the energy source for refrigeration many methods can be employed. Solar energy can be converted to mechanical energy to drive the compressor of a standard vapour compression system or electricity can be produced by a solar engine driving a generator which then operates standard electrical refrigerators. Since we can convert solar energy more efficiently to heat than to mechanical or electrical energy the use of a vapour absorption refrigeration system with solar energy is considered to be the best solution at the moment. This kind of machine where the pressure of the refrigeration vapour is raised by heating instead of by mechanical compression, can function either continously or intermittently. For application in developing countries an intermittent absorption refrigeration process has been considered. The continous process requires too high temperatures and therefore the use of concentrating solar collectors which are presently expensive.

In the intermittent absorption refrigeration cycle the best known fluid used is an aqueous solution of ammonia. Heat is obtained from flatplate solar collectors. The ammonia water mixture is heated directly by solar energy in the generator (boiler), when the temperature increases ammonia begins to evaporate. The vapour flows to a condenser (which is cooled) where it condenses. The liquid then expands through an expansion valve. The low-pressure liquid reaches the evaporator in which it absorbs the heat of the material being cooled and evaporates (e.g. chilled water for air-conditioning purposes and brine for ice production). The vapour that formed flows to an absorber where it meets a spray of weak ammonia solution and is absorbed. In the cooled absorber the concentration of the mixture increases and it is pumped to the boiler and the cycle is then continued, Duffie and Bechman (1974).

Another method suggested for application in developing countries is the evaporative food cooler which consists of a container surrounded by a piece of suitable cloth the lower part of which is submerged in a tray containing water. The water gets absorbed by the cloth which acts like a wick. As the water evaporates the food in the container is cooled. Various types of coolers (basket and cupboard) could be constructed. Earthernware coolers (vessels) are used extensively in Asia for cooling water for drinking and small coolers have been used in Europe to cool butter and cheese until the second world war. The evaporative cooling method is not considered a refrigeration system but only a means of space cooling in the tropics. The lowering of temperature achieved in an evaporative food cooler is insufficient for food preservation.

Although a considerable amount of research and development work is being carried out in the USA, Japan and other countries on solar refrigeration and air-conditioning, nothing definite is known at the moment on the best methods of obtaining cooling and refrigeration.

2.7 Solar Cooking

Several traditional fuels have been used for cooking. Each of these fuels has a varying degree of cooking efficiency. Unlike traditional cooking methods solar cooking must be done in the open. The solar hot box is the main type of cooker which has been developed. It is an insulated box with a glass cover which is set out in the sun and oriented manually. The interior cooking chamber is coated black. Food to be cooked is placed in shallow utensils in the solar box. In the umbrella type, parabolic reflector solar cooker, the sun's rays concentrate on a focal point on which a cooking pot is placed. A detached solar collector and cooking chamber unit has also been developed. In this system the heat-transfer fluid (water converted to steam or heat-transfer oil) is heated in a separate collector (Flat plate type or concentrating type). The heated fluid is then transferred to a cooking chamber which can be located within the house where the cooking is done. These systems have not been extensively field tested and no comprehensive study of solar cooking technology has been attempted.

2.8 Solar Power Generation

i. Conversion of Solar Energy into Mechanical Energy

The conversion of solar energy to mechanical energy and direct conversion of solar energy to electrical energy (photovoltaic approach) has been the subject of extensive research in recent years. Efforts to generate power by the use of heat engines have been studied. Most efforts have been centred around ways of collecting and concentrating solar energy. Solar concentrators in the form of paraboloids (dishes), parabolic cylinders (troughs) and other shapes have been investigated. A design which involves a large array of flat mirrors mounted on the ground and continuously oriented to reflect the sun on to a high-pressure steam boiler located at the top of a high tower having a turbogenerator at its base is also being studied. The term 'solar engine' designates an engine operated by solar energy. A working fluid (freon, propane or butane) is first evaporated directly in flat-plate solar collectors or by hot water obtained from solar collectors and circulating in a heat exchanger (evaporator). The vapour formed expands in a reciprocating or rotating engine and it flows to a condenser (which is cooled) from which the working fluid (now a liquid) is reinjected into the evaporator by a pump operated by the solar engine itself.

Flat-plate solar collectors (capturing direct and diffuse solar radiation) are suitable for use in low temperature solar engines (less than $100^{\circ}C$). For medium and high temperature solar engines focussing solar collectors which track the sun and traps only direct solar radiation are used. Air can also be heated to a relatively high temperature by solar energy and used as the working fluid in a solar engine (hot-air engines). The heat generated in a solar collector array can in principle be used to operate various forms of heat engines (rankine and sterling cycle engines and others) and these may be used in solar thermal power systems. Solar engines may be used to produce mechanical or electrical energy for water pumps, minor industrial operations or for lighting purposes. Small solar energy plants ranging from a few KW of mechanical or electrical net output to 100 KW and more are a possibility for establishment in rural areas of most developing countries. Solar pumps are already in operation in a number of developing countries and solar power plants (10 KWe) have been constructed for demonstration purposes. Energy storage is still the most important problem which must be satisfactorily solved. The solar power station which is situated at Ideillo in the French Pyrenees is a one megawatt solar furnace which is powered by the sun's rays being reflected on to the walls of a solar furnace. A 10 MWe system has also been established in Bariston, California, U.S.A.

ii. Direct Conversion of Solar Energy to Electrical Energy

The silicon solar cell which produces an electric potential when illuminated by solar radiation is believed to be a highly reliable and stable device when protected from the environment (other types of cells have also been used). The photovoltaic (PV) power system consists of a solar cell array, energy storage and control devices. The cells are electrically connected and the wire harness collects power from the array. Energy storage consists of lead-acid cells connected in series and or parallel to provide the desired voltage. Voltage regulation is also provided. From 1958 to recent years the major application of solar cells has been in outer space where it is the power system of choice, supplying power to hundreds of spacecraft. In the 1960's Japan successfully employed solar cells in a number of instruments in communication and navigation aid applications. From the early 1970's US firms began marketing photovoltaic (PV) power systems for various applications. On December 16, 1978 the world's first village photovoltaic power system began operation, providing the residents of Schuchuli (south western Arizona USA) electric power for potable water pumping, lights in the homes and community buildings, family refrigerators and other services, Louis et. al. (1979).

It is believed that experience with installed PV systems which are currently powering a variety of services for users in some rural areas confirms that PV systems can provide a viable approach to meet many of the basic energy needs in the developing countries.

2.9 Space Based Solar Power Systems

In recent years attention has also been given to a space based solar power system (SSPS) for large scale power production. It depends on the collection of solar energy at geostationary altitudes using the photovoltaic principle and converting the energy into microwave energy for transmission to locations on the ground. The microwave energy is to be reconverted back to electrical energy.

3 WIND ENERGY

Probably the oldest method of capturing the wind was the sail. First in ships and then on land. It is believed that two thousand years ago the Persians used wind to grind corn and pump water. Denmark in 1916 was producing electricity from wind generators. In the USA and many other countries wind mills are in daily use. As with solar energy, with wind energy we are rediscovering long forgotten skills. The World Meteorological Office has estimated that at least 20 million megawatts of wind power is available at various sites around the world. By comparision, the world total electrical generation capacity is under 5 million megawatts. Modern utilization of wind power is mainly aimed at electricity production and plant of this kind is now in operation in many countries. Wind mills as a source of mechanical power continue to be an appropriate technology for rural applications, to pump water for domestic and other uses, to perform agricultural tasks (grinding corn, crushing sugar cane and threshing) and for the generation of electricity in more recent times.

The basic elements determining the energy obtainable from a wind mill, are the wind speed, the size of the area swept by the rotor and the conversion efficiency of the plant. Wind mills however, are designed to give their maximum power capacity at a chosen or rated wind speed. In theory the maximum a wind mill could extract is 59.3 per cent power in the wind. In practice efficiency may be reduced to about 30 per cent. Although wind is a free and inexhaustible source of energy, it does not always blow. One cannot therefore rely absolutely on power from the wind at a given moment, however windy the chosen site may be. The amount of useful power produced also depends on the ability of the user to use it when it is produced. In most parts of the world winds blow at random times, and if the energy cannot be used when the wind provides it and cannot be stored against the time that it is actually needed, as electrical energy in storage batteries or as water pumped to an elevated reservoir, the usefulness of the wind device is questionable. For this reason one of the essential first steps is to obtain information on average wind speeds at the site proposed, including data on the length of period during the year that the wind blows with a speed greater than a given maximum, together with other useful data.

At present there are a number of wind powered pumping systems and wind powered electrical generators which are commercially available. Mechanically they are said to be almost similar to fossil fuel powered engines in terms of reliability. The cost of a wind system is closely linked to the type of the rotor and height of the tower. A large part of the cost is the cost of the tower iself. When the use of the wind mill to generate electricity is contemplated the necessary details of matching the operating characteristics of the generator to the properties of the wind mill require some engineering expertise. The development of technologies for the exploitation of wind energy is now geared not only to technical problems of manufacturing and operating large scale facilities but also to the integrated operation of wind power stations and energy storage systems. Future work will therefore help to develop low cost, simple and low maintenance small scale plants and to integrate them into other energy producing systems. Large plants are also being investigated by a number of countries for operation in integrated systems with other power plants.

4. BIOMASS

The convenient term to describe energy resources from organic matter is biomass. All fossil fuels (oil, gas and coal) were once biomass. Plants, trees and organic wastes have a great energy potential. Roughly 30 per cent of the earth is covered by trees and about half of all trees cut down around the world are used for cooking and heating principally in the developing regions. If "farmed" properly, wood is an easily renewable source of energy.

Wood and straw burning boilers for central heating have been developed. A study carried out by the Ford Foundation (USA) has recalled that oil, gas and coal consumption in the pulp and paper industry could be cut by an incredible 75 per cent if this industry burned their wood wastes. This applies to similar industries in other countries. Burning waste products for generating electrical power is another example. A considerable amount of Hawaii's electricity is generated by burning sugar cane wastes. The waste disposal problem could therefore be solved by using waste material as a whole or part substitute for oil in power generating plants. Considerable research and development has been undertaken by a number of countries on the microbiological conversion of plant materials to liquid fuels, such as the production of acetone, butanol and ethanol. The most competitive alternate liquid energy to fossil energy may be provided by alcohol fuel. Brazil has already launched a programme to dilute its petrol (up to 20 per cent) with ethanol. The generation of methane fuel gas by means of the classical "anaerobic digestion", of animal, agricultural and human wastes is another new source of energy normally referred to as biogas production. The fact that organic material, rotting under conditions where it is out of contact with air, will produce a inflammable gas, has been known for centuries, particularly in the phenomenon of marsh gas. Methane gas (biogas or gobar gas) is now produced extensively in India, Taiwan, China, Korea, Bangladesh and in other countries mainly for use in rural areas.

4.1 Fuel Wood and Charcoal

Trees are a renewable energy source, however, this traditional source is growing scarce and expensive as forests are receding in most countries and even grass lands are becoming deserts. At present it is the cost of transport that makes wood unattractive commercially as a fuel. The calorific value of wood increases as the green timber dries. Wood dried in the open air is 6000 Btus per lb. compared with 13,000 Btus per lb. for coal. So the wood equivalent of the coal weighs twice as much and occupies four times the area. Space is the first thing the wood user needs. Time is also another factor to transport, saw, split and stack wood. Wood has been used for centuries and wood undoubtedly will remain the main energy source in rural areas of developing countries for many more years to come.

Third world deforestation is advancing rapidly. The overwhelming preponderance of wood cut in the developing countries is used for fuel. Few countries have conducted successful reforestation programmes even though this is probably their most potentially lucrative energy-production investment. Reforestation especially with fast growing species such as eucalyptus, ipil-ipil (in recent years) and other varieties purposely grown for use as firewood is now being undertaken by a number of countries. Social forestry which involves growing trees in common village lands could also make a valuable contribution.

Wood charcoal is another source of energy. It has a much higher calorific value (weight for weight) than the wood from which it is produced. In the process of carbonization, the water in the wood (more than one-third the weight of the wood) is expelled and a considerable saving in transport costs can be achieved. However, part of the energy in the wood is also lost in this process. Charcoal is a clean fuel (smokeless) and is ideal for domestic and industrial use.

4.2 Biogas (Methane gas CH_4)

Biogas or gobargas is extracted by the anaerobic digestion of animal, human and agricultural wastes. It is decades old and the technology is well known. A basic way of obtaining biogas is by mixing cowdung and water. The digestion is carried out by bacteria which are present in the manure. Its functional uses range from cooking, heating and lighting to powering engines for electricity generation and for other uses. Methane bacteria are sensitive to certain environmental factors. Their growth is inhibited even by small amounts of oxygen and it is essential that a highly reducing environment be maintained to promote their growth. The bacteria are sensitive to changes in pH and gas production is normally satisfactory between 6.6 and 7.6 pH. Sudden temperature changes should also be avoided. Process temperature at the optimum range of $30^{o}C - 38^{o}C$ should be maintained. After fermentation, the organic matter produces not only gas but also large amounts of effluent (liquid slurry and sludge) that make excellent fertilizer. The liquid slurry could be removed daily from the outlet chamber and the sludge that settles at the bottom of the digester is obtained when the digester is periodically emptied.

In China the most rapid expansion of biogas has been registered in the province of Sichuan. It has about 5 million biogas plants. The gas produced is mainly used for cooking and lighting and sometimes to genereate electricity. India has also undertaken considerable work on biogas production. Various types of digesters have been tested and over 25,000 biogas plants have been installed. It is believed that the anaerobic digestion process which generates methane gas is a promising answer to future energy needs of rural areas, however, in practice very large numbers of animals (pigs, cows or poultry) are required for this purpose.

4.3 Ethanol

The art of fermentation of a variety of plant products to produce alcoholic beverages has been known for centuries. The processes of producing alcohols all of which are inflammable liquids involve the growth of microbial populations under anaerobic conditions (not in contact with air) utilizing the nutrients found in various plant sources and converting the carbohydrates (sugars and starches) of the plant materials to various alcohols. When the alcohol is to be used as a liquid fuel it must be separated in a sufficiently pure form by conventional distillation.

The technology of the manufacture of ethyl alcohol obtained from raw materials of vegetable origin and running of vehicles with a petrol-alcohol mixture is now known. Brazil is to-day running thousands of its automobiles on the petrol-alcohol mixture. Experiments concerning the addition of alcohol to petrol have shown that in proportions up to 20 per cent (alcohol) no modifications of the motor is required. Alcohol may also be added to diesel up to about 4 per cent.

Today the raw material most widely used in the production of alcohol is sugar cane. According to the Brazilian experience one ton of sugar cane produces on average 95 Kg. (200 lbs) of sugar and 7 to 12 litres of alcohol as a byproduct. In a process for the exclusive production of alcohol an average yield of 60 to 70 litres of alcohol per ton of sugar cane is achieved. Other materials which could be used for alcohol production include sorghum, cassava (manioc) sweet potato and celullose residues.

The establishment of small-scale plants (distilleries) for the production of alcohol located in strategically selected points, specially in developing countries., will make possible the incorporation of new land into the productive system. This has the added advantage of fixing the rural population in the region as they will benefit from the production of energy inputs.

4.4 Waste Materials

Agricultural waste materials are already used in many countries for industrial purposes (straw for the manufacture of paper), as fertilizers, animal feed and as a fuel. The use of some agricultural wastes for energy production will allow additional value to be gained from them while the previous benefits are still retained. Wood wastes from various industrial concerns using wood as a raw material, straw, coir dust, paddy husk, bagasse (sugar cane waste) and other materials could be used as a source of energy. Waste has always existed in our society of plenty - always and everywhere. We have in the past ignored it, thrown it away, or burned it uselessly. Considerable attention is now being given to the briquetting of various waste materials for use as a fuel. In Hawaii bagasse is used along with residual leaf trash to produce steam for electricity generation. Waste materials are therefore becoming important as an alternative energy source.

5. TIDAL ENERGY

Other possibilities of opening up new sources of energy mainly involve the use of marine phenomena which include tidal energy, wave energy, salinity gradients of the oceans, temperature gradients of the oceans and ocean currents.

The energy involved in tidal movements is immense and inexhaustible. The energy of the tide can be harnessed and converted to electricity by a process similar to that used in the production of hydro-electricity. The size of the tide is the difference between 'high' and 'low' water and its size varies with the season and with geographical location. Given that the tidal movement is of sufficient size it could be harnessed for power generation. The one-way cycle is the simplest arrangement and entails the closing of an estuary or bay by a barrage to create a large basin. The potential energy of the water is utilized as the basin empties. The cycle takes place in three stages;the filling phase with the rise of the tide, the waiting phase in which the tide has reached its maximum and the sluices closed and a generating phase when the water is fed through turbines which produce power by the difference in water level betwen the basin and the sea. The possibilities offered by very large tidal power stations are great. Perhaps the best known is at La Rance in France which has an output of 240 MW. Of the British methods being researched is one known as the Salter Duck which extract power from the up-and-down motion of the waves. Recent advances in turbine design and barrage construction techniques make these power stations even more attractive now. Tidal energy remains a great potential source of electrical power but its exploitation is not likely in the near future.

6. THERMAL ENERGY OF WATER

The feasibility of exploiting this type of energy was first demonstrated in France when studies revealed that it was possible to produce energy from a small temperature difference between two vast bodies of water. Temperature differences are found where there is a warm surface layer of water heated by the sun and deep below cold water. The temperature difference should normally be about 20°C.

This might necessitate pumping from great depths. Sea thermal plants can also make fresh water a by-product of the process.

The sea is the largest collector and reservoir of solar energy on earth. Of the practical large-scale solar proposals only sea thermal power can produce 24 hours a day output. Other solar energy methods are limited to about 8 hours a day. To permit continuous generation with those other methods large energy storage systems are also required.

The sea solar power systems or ocean thermal energy conversion (OTEC) power systems for generating electricity utilizes a floating platform much like a present day oil rig which is totally self-contained. The plant consists of an evaporator, a turbogenerator and a condenser. The warm surface water is led through the system where its heat vaporizes a working fluid. This vapour drives the turbine, producing electric power in the generator and then is condensed by the colder water from the ocean depths. The working fluid is finally directed back to the evaporator to be reused. The water is returned to the ocean. Difficulties however, have been experienced in obtaining the colder water from the ocean depths.

Although attempts have been made to demonstrate power generation by using the thermal energy of water, OTEC power systems are still in the experimental stage. Available information reveals that they are expensive to build at present. The possibilities are that such plants may be a viable source of power in the not too distant future. Land based OTEC plants are also being studied. NARESA has also undertaken studies on the feasibility of establishing OTEC power systems in Sri Lanka.

7. GEOTHERMAL ENERGY

Geothermal resources have been known since ancient times specially to support establishments for therapeutic bathing (therapeutic use of hot springs). At the beginning of the 20th century, a new application of geothermal steam was used for the generation of electricity. Geothermal energy is the natural heat contained within the earth. Earth geothermal resources mainly exist in areas of the world that have experienced recent volvanic activity. They may also exist in other areas. Geothermal energy has economic significance where the hot rock at depth is fractured or has spaces that permit hot water or steam to circulate and carry heat from the rocks to the surface, by way of a natural channel or if a geothermal well is drilled. It is a resource that can be used only near natural occurrences. When hot water or steam is available it provides a source of energy for electricity generation, space heat, drying and refrigeration.

When electricity is to be produced the geothermal steam itself could be used directly to drive a turbine. A synthetic refrigerant (working fluid) may also be used for the purpose of driving the turbine in which case heat exchangers are needed. These are metal plates or piping to keep the geothermal hot water and the fluid separate and yet capable of transfering heat easily. High temperature geothermal water and steam have been exploited in countries such as Iceland, Italy, Indonesia, Japan, New Zealand, the Philippines, South America and USA where volcanic activity has occurred within the geologically recent past.

8. HYDRO POWER - MINI PLANTS

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 very rapidly. Small scale, low-head hydro electric units normally refer to those capable of generating 5 - 15 KW at heads of 10 - 20 feet (3 - 6 m). The units can also perform useful mechanical tasks directly. Mini hydropower plants or midget water power stations are now being installed at various points as an alternative source of energy. "Micro" hydro power package power plants are now available from a number of manufacturers. It has also been reported that small wooden turbines are being made in the Soviet Union and China and it may be worthwhile to pursue the idea of a wooden turbine design for use in other countries.

Most of the world's untapped water power is in the developing countries. Africa for instance, generates only 2 per cent of the world's hydropower but holds over 20 per cent of the potential. A significant growth is expected in the use of small water driven turbines over the coming decades as there are literally millions of river sites around the world where individual and corporate energy needs could be met by the installation of water powered generators. The Chinese have made it a public policy to decentralize energy sources and about 20 per cent of China's entire electrical needs are supplied by some 60,000 small hydropowered installations. As soon as the cost of small water turbines falls demand should grow and if this is conbined with legislation to encourage the use of river power, significant energy savings can be expected from this source in the future.

9. HYDROGEN

In general the greater the number of hydrogen atoms attached to carbon atoms in a hydrocarbon molecule the greater the energy content of the fuel. It is the large hydrogen component in methane (natural gas) and gasoline that gives these fuels their high energy content. The generation of synthetic hydrocarbon fuels and the use of pure hydrogen as a fuel are areas which have attracted attention in recent years. The possibility of obtaining the fuel hydrogen by the electrolysis of water has been studied. However, the process requires large amounts of electricity.

There has been much technical discussion on the use of pure hydrogen as a fuel. One of the great advantages of this substitution is that the principal cumbustion product is water. There are also several disadvantages in the use of raw hydrogen for aircraft and automobiles. The density of hydrogen is very low and even in the liquid state large volumes of the product would be required for various uses. The container tanks would therefore have to be large and super insulated to prevent the cryogenic hydrogen from boiling away. It is also believed that controlled thermonuclear fusion to generate electricity could provide the key to achieving an inexhaustible supply of synthetic hydrocarbon fuels including the generation of hydrogen by electrolysis of water. The fusion reaction is yet in the experimental stage and as mentioned earlier it may be a long wait for a major breakthrough in this area of research. German and U.S. researchers feel that hydrogen could be used for heating and as a motor fuel and can be produced from water or coal. The storage problems appear to be nearest to solution as a result of breakthroughs in the use of hydride tanks. Since hydrogen forms hydrides with certain types of metals and alloys, it is possible to use this property to solidify hydrogen.

Solid hydrides are more advantageous from the weight standpoint than hydrogen gas contained in cylinders. Apart from the electrolysis of water, hydrogen has also been produced through catalytic reaction of steam with coke and a new technique has been developed for the production of hydrogen by applying an electric current to a mixture of powered coal and water. These processes require a greatly lowered electrical consumption. The weight and cost of tanks yet remain a problem both for liquid hydrogen and for hydrides. It is however, believed that hydrogen is a leading contender as an alternate fuel.

SUMMARY

It is obvious that whilst our dependence on oil, gas and coal will not slacken for some considerable time our world does offer a wide variety of other possible energy sources. We are now nearing the end of the beginning of the painful transition from a fossil fuel economy to one that employs inexhaustible, safe and clean energy sources. Although some of these energy forms (other than nuclear energy) cannot as yet be called upon to provide an economical source of energy in the same magnitude as oil, gas and coal there exists immediate applications with special relevance to the needs of the rural areas where the greater mass of our people live. Tomorrow's energy is one of the key problems of the developing world and a matter for serious concern for the industrialized nations. In selecting the techologies to be developed in countries like Sri Lanka it must be recognized that major financial resources are now being devoted to research and development work on alternative sources of energy in the more advanced countries. The immediate concern of a local programme should therefore be on relatively simple and adaptable technologies, those which are not capital intensive and need minimal R and D to make them useful. For more complex technologies the strategy should be merely to keep abreast of developments and to transfer the relevant technologies for local use after they have been proved feasible elsewhere. It is clear that no single energy source can meet the entire demand of the world or of any particular country. The optimal utilization of a mix of different types of energy sources have to be adopted depending on the particular resources and conditions in each country. The necessity for discovering

alternative, economically viable sources of energy cannot therefore be over looked.

CHAPTER 4

GENERAL GEOGRAPHY AND GEOLOGY

Sri Lanka (Ceylon) is a tropical island and lies 32 km. to the east of the southernmost extremity of Peninsular India. It has an area of 65,600 square kilometres and is 432 km. long and 224 km. at its greatest breadth.

The Island may be divided into two main physiographic divisions

1. The low lying coastal plain with little relief and traversed by rivers which have reached their base level of erosin.
2. The central highlands with immature drainage patterns and marked relief abounding in numerous strike ridges, hills and mountains.

The coastal plain is narrow in the western and southern parts of the Island. The general level varies from sea level to about 150 metres and some erosion remnants may rise to 300 metres or more above sea level. The central highlands rise steeply from the coastal plain - mainly in certain areas towards the south. The highest mountain (Pidurutalagala) attains an elevation of 2527 metres above sea level.

Sri Lanka lies in the monson region of south-east Asia and it has a humid tropical climate. The division into a Wet Zone and Dry Zone which merge in an Intermediate Zone is one of the most widely recognized geographical features of the Island. In Fig. 1 the rainfall pattern is shown, clearly demarcating the Wet and Dry Zone. The average rainfall varies from below 1250 mm in the north-west and south-east parts of the lowland zone to over 5000 mm in the south-west slopes of the central hill country. The mean rainfall for the Island is 2000 mm. In the Wet Zone areas the average mean temperature varies between 21.11°C and 29.44°C and in the Dry Zone it may be nearer 32.22°C. In the highlands the mean temperature ranges between 14.44oC and 25.56°C according to elevation.

The rivers are for the most part radial. The upper reaches are mainly confined to the central hill country. The radial pattern is the dominant element in the drainage pattern of Sri Lanka. The greatest problem of Wet Zone hydrology is that of flood control. Inundation of low lying areas is almost inevitable and vast stretches of ground are subject to serious flooding during the wet seasons. This has resulted in the development of deep and extensive deposits of alluvial material along the lower reaches of the major river systems draining this region. In the Dry Zone it is a seasonal shortage of water which is a problem. Very few rivers rise in the Wet Zone and flow into the Dry Zone.

The main concentration of settlements is in the Wet Zone in the whole of the western, south-western and central

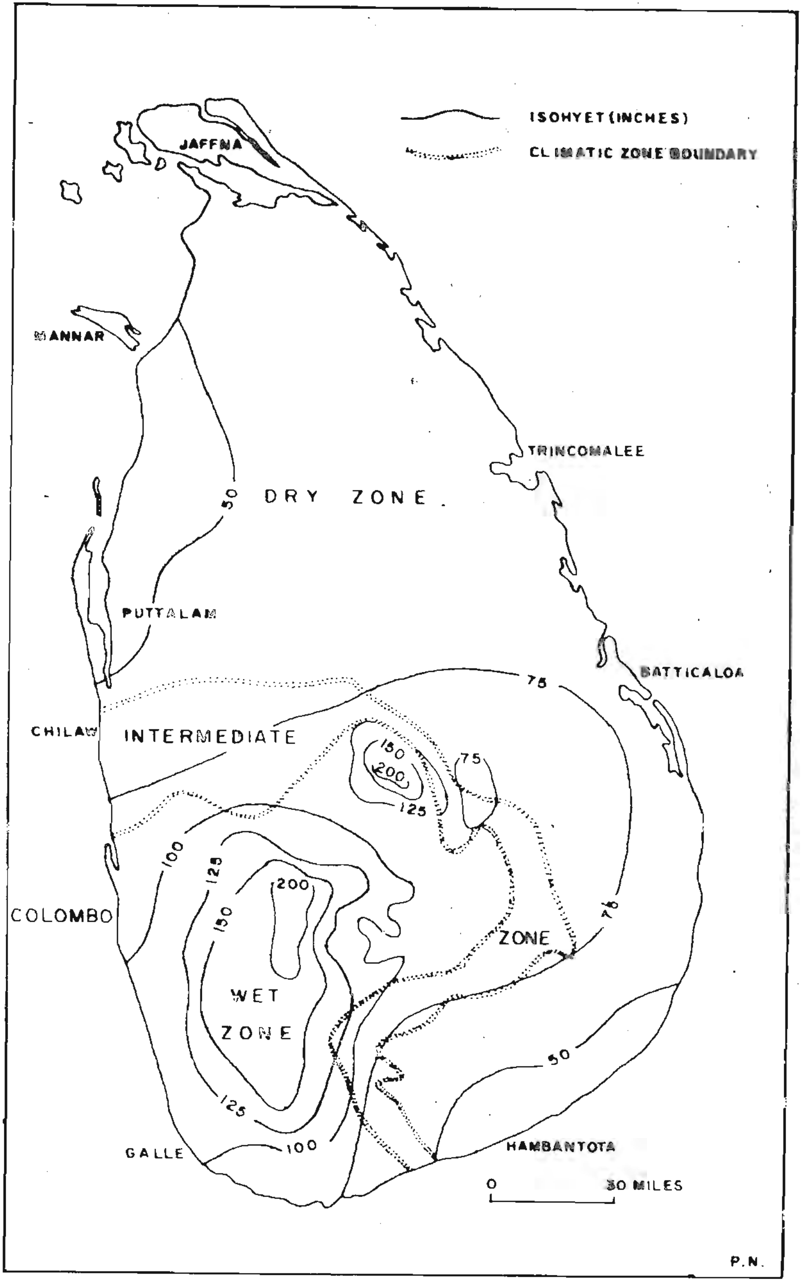

FIG:1 - RAINFALL PATTERN - SRILANKA

hills. In the Dry Zone areas, for example, in the north, north-central and east-central parts of the Island the concentration is light. The population of Sri Lanka in 1963 (Census of Ceylon 1963 - Department of Census and Statistics) was approximately 11.5 million and in 1971 (Census of Ceylon 1971) the population was 12.7 million. In 1979 it was 14.5 million and at present it is around 15 million growing at the rate of 1.7 per cent per annum. About 80 per cent of this population lives in the rural areas where agriculture is the main activity.

Over 90 per cent of the surface area of the Island is underlain by Precambrian rocks consisting of a complex series of high-grade metamorphic rocks, most of which have been derived from sediments and altered by one or more metamorphisms. Associated with these metamorphic rocks are granites and granitoid rocks of igneous origin. Fig. 2 shows the outcrops of the main geological formations in the Island and Table VII is presented to show the general succession of formations and the important mineral deposits in Sri Lanka.

Recent formations include a variety of unconsolidated materials, coastal sandstone, coral and shell formations. By far the most extensive deposits of recent origin are the alluvial deposits which are widespread along the lower reaches of the major river systems of the Island. The Pleistocene deposits which are developed in the western and north-western parts of the Island are mainly gravels and red earths and laterites are well developed in the south-west sector of the Island and are clearly residual type deposits.

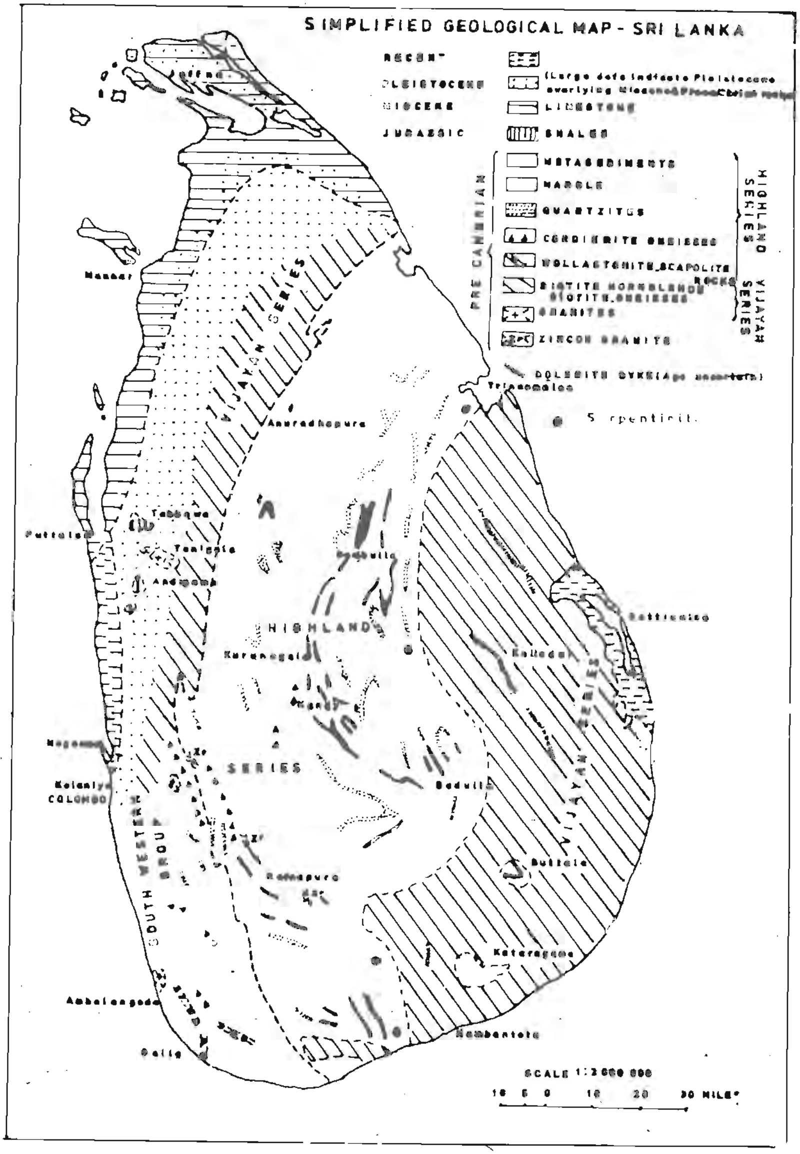

FIG:2 – GENERAL GEOLOGICAL MAP – SRI LANKA

TABLE VII

GENERAL SUCCESSION OF GEOLOGICAL FORMATIONS AND PRINCIPAL MINERAL DEPOSITS IN SRI LANKA

Principal Geological Divisions		Principal Formations	Important Mineral Deposits	Others
Era	Period			
ANTHROPOZOIC	HOLOCENE (RECENT)	Recent residual and alluvial deposits, blown sand, coastal sandstone, coral and shell formations, beach mineral sands, gem gravels, peat, lagoonal and estuarine deposits	Kaolin, ball clay, refractory bond clay, residual and alluvial clay, silica sand, ilmenite, rutile, zircon, monazite, garnet, gem, coral, shell sillimanite, clay ochers.	Thorianite, thorite, baddeleyite-peat
CENOZOIC	QUATERNARY (PLEISTOCENE)	Laterites (may extend from Recent to Tertiary Periods), gravels, red earths.	Gem	Laterite, limonitic iron ore (low grade)
	TERTIARY (MIOCENE)	Limestone	Limestone	-
MESOZOIC	JURASSIC	Shales, Carboneceous shales and arkosic sandstone.	Shales	-

TABLE VII (Contd.)

PALAEOZOIC	-	Abesnt	-	-
ARCHAEOZOIC	PRECAMBRIAN	Highland Series (metasediments) Vijayan Series (gneissic complex) Southwestern Group (gneisses and metasediments) Intrusives, (granites, dolorite dykes, pegmatites)	Marble, quartz, felspar, graphite, mica, apatite	Magnesite magnetite allanite cordierite, chert wollastonite sillimanite copper, serpentinite

(Modified after Herath 1980)

The largest development of sedimentary rocks occur in the north-western coastal belt extending from the Jaffna Peninsula in the north to the south of Puttalam on the west coast. This formation is of Miocene age and the rock type is a massive limestone of marine origin which is fossiliferous. Jurassic rocks are limited in extent and they are exposed in the Tabbowa, Andigama and Pallama areas north of Chilaw. These sedimentary rocks are composed of sandstone, grits, arkoses and shales. Similar Jurassic (Gondwana) rocks occur below the Miocene limestone of the Mannar area (Petroleum surveys - drill cores).

The Precambrian crystalline rocks which cover the major portion of the country consists essentially of a charnockite-metasedimentary series (Highland Series) and a complex of gneisses, granites and migmatites (Vijayan Series and the South-Western Group of rocks). The Igerous rocks occurring in Sri Lanka are mainly pegmatitic materials, zircon granites, some dolerite dykes and a few granites. Pegmatites of economic value are known in the Rattota, Talagoda and Alutepola areas. Numerous other pegmatites have been observed in other parts of the Island. Zircon granites outcrop in the Balangoda, Loluwa and Parakaduwa areas. Dolorite dykes are confined to the Eastern Province (Maha Oya, Elahera, China Bay and Kantalai). Granites are developed in the Tonigala, Ambagaspitiya and Aluthgama areas.

Metamorphic rocks which cover the major portion of the Island are of Precambrian age and some rocks are over 2000 million years old. Three main groups are recognised:

(a) Highland Series - This Series is characterised by metamorphosed sediments and charnockitic rocks. The main rock types exposed are quartzites, marbles (mainly dolomites), garnet - sillimanite - graphite schists, granulites and gneisses of various types including a variety of charnockitic rocks.

(b) Vijayan Series - This Series is mainly composed of granites, gneisses of various types and migmatites.

(c) South Western Group - This group is similar to the Highland Series. There are however differences between the two units in terms of both lithology and metamorphic history. Rock types in this group include thin quartzites, wollastonite bearing rocks, cordierite bearing gneisses, coarse charnockitic rocks and appreciable amounts of chert.

These rocks have been folded into a series of synforms and antiforms, generally trending in a north-west south-east direction. A good deal of controversy still remains about the subdivision of the Sri Lanka Precambrian. What can be generally agreed however, is that the structures are every where complex. In recent years however, the boundary between the Highland Series and Eastern Vijayan has been recognized as a mineralized zone. A number of serpentinite rock outcrops have been located along this boundary (Fig. 2) and the Seruwila copper-magnetite deposit is also confined to this zone.

SUMMARY

Sri Lanka is mainly composed of Precambrian rocks. The monazite occurrences (beach mineral sands) are the only deposits which may be of some value as an energy source in the distant future. Uranium surveys are being undertaken by the Geological Survey Department, however, the prospects for locating economic deposits are poor. Exploration for oil is in progress (Ceylon Petroleum Corporation). The only worthwhile resource as far as energy in Sri Lnaka is concerned is the water power potential of the country which has enabled hydropower development. A number of hot springs have been identified and these do not show any promise as an energy resource. The peat deposits are of a poor quality and are of no economic value. Further surveys may have to be conducted to locate good quality deposits. Sri Lanka is poor in energy resources.

CHAPTER 5

PRESENT ENERGY SITUATION AND MAIN RESOURCES - SRI LANKA

GENERAL STATEMENT

The pattern of primary commercial energy sources varies according to local abundance or shortage. In the absence of coal, petroleum and natural gas, Sri Lanka has to depend on imports of essential fuel materials. Wood remains the main fuel source in rural areas. All petroleum products and limited quantities of coal are imported. The Ceylon Petroleum Corporation is the sole importer and distributor of petroleum products and it operates a refinery at Sapugaskanda. This organization has also undertaken activities in connection with oil exploration in the country. Water power potential has enabled hydropower development. The existing stations (hydropower and thermal) with a total capacity around 430 MW (1983) generated nearly 1700 Gwh of electrical energy. Ninety percent of the electricity generated was from hydropower. The total hydropower resources (with the existing projects) were estimated in 1968 for an installed capacity of around 1600 MW producing an average annual putput of 6260 Gwh (Table XII). It has to be noted now that projects considered to be economically not viable 17 years ago could be highly viable today with the steep rise in the oil prices during the intervening period.

Approximately 50 million tons (wet basis) of low grade peat or 5 million tons (dry basis) have been proved to occur in the Muthurajawela swamp north of Colombo. The deposit cannot be considered a promising one. Deposits of uranium have so far not been observed. Promising areas for uranium exploration have however been identified for detailed investigation. Thorium minerals occur in the Island, monazite being the most important thorium bearing mineral. Geothermal resources are limited. A number of hot springs have been identified and they cannot be considered as a potential resource for energy purposes. Figures 3 and 4 are presented to show the energy resources of Sri Lanka.

ENERGY CONSUMPTION PATTERNS

In Sri Lanka the total approximate energy consumption pattern, Fernando (1982), is as follows:

Firewood - 60 per cent
Petroleum Products - 27 per cent
Hydro electrocity - 13 per cent

The total energy consumption for the year 1979/1980 has been estimated at 10,000 Gwh (electricity replacement) of which 1200 Gwh was produced by electricity, 2700 Gwh from oil products and 6100 Gwh by traditional fuels, such as firewood and agricultural wastes. The primary source of energy is therefore from traditional sources. Around 90 per cent of the households in Sri Lanka use kerosene for

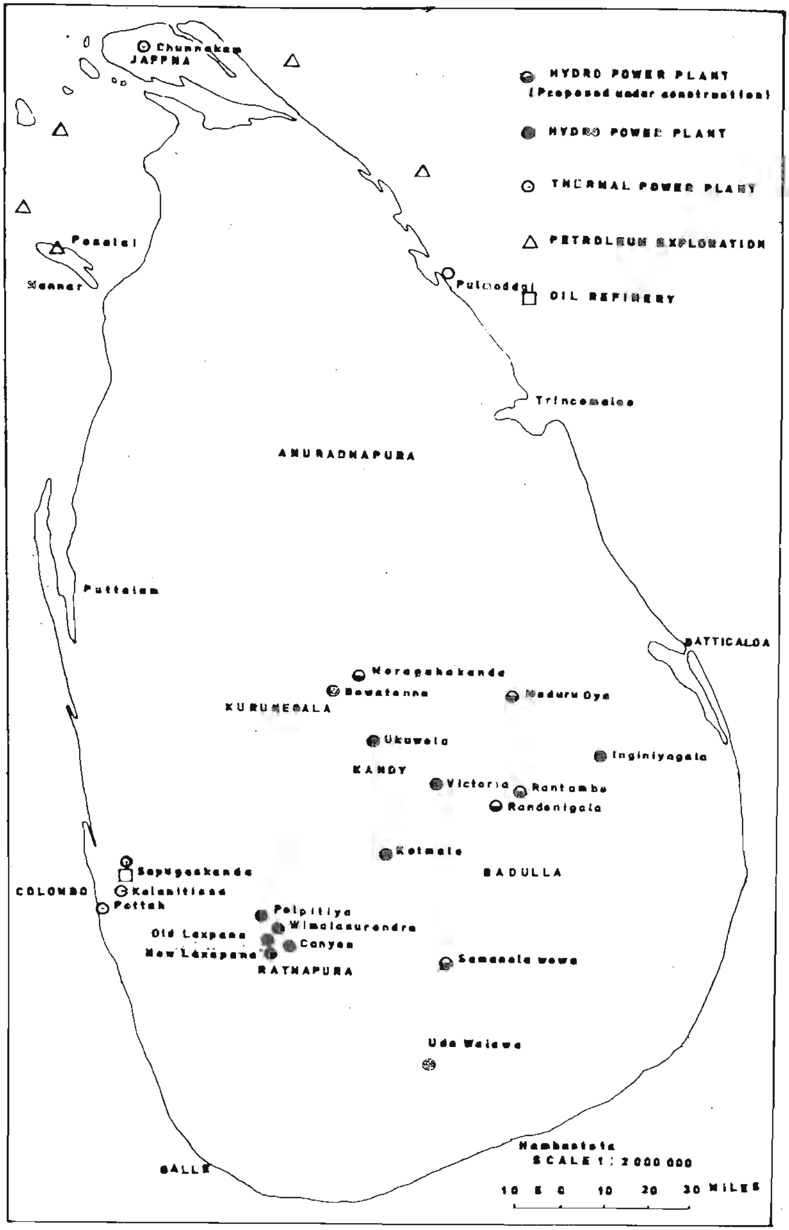

FIG:3 - ENERGY RESOURCES - SRI LANKA

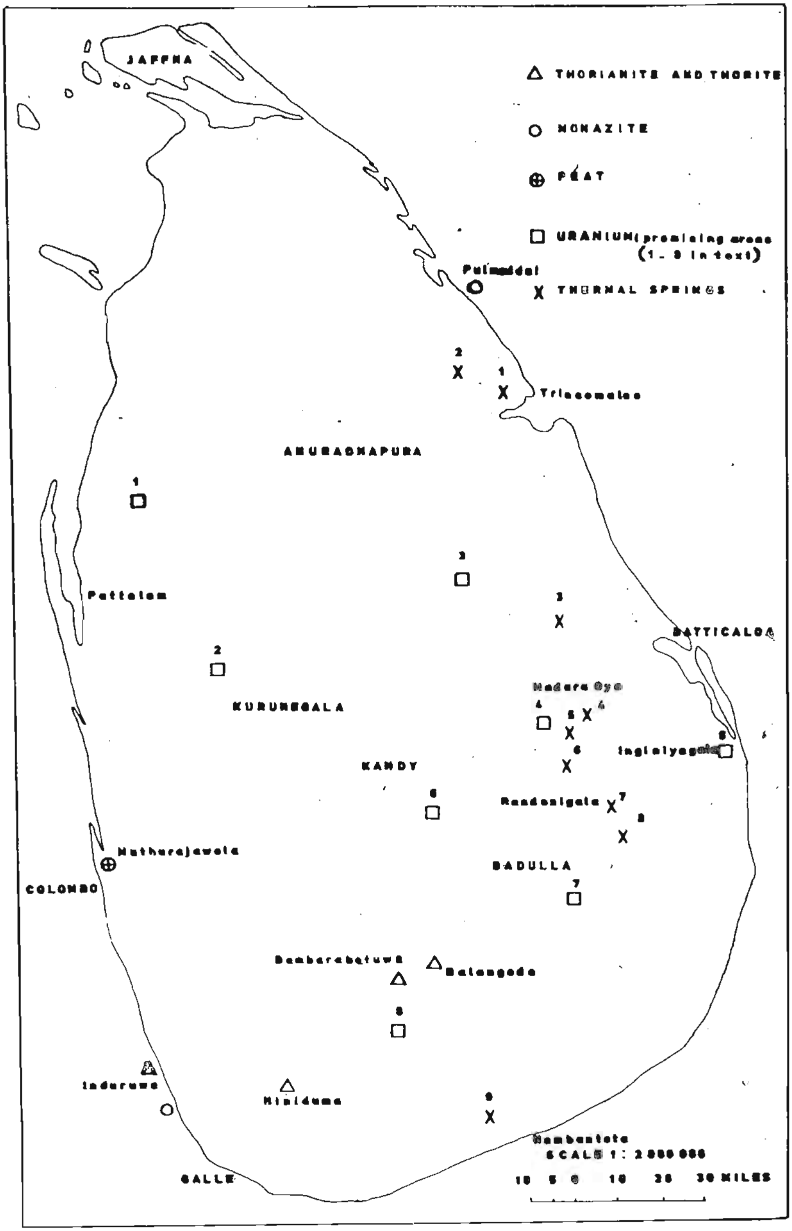

FIG:4 - ALTERNATE ENERGY RESOURCES - SRI LANKA lighting and firewood for cooking purposes. Nine per cent of the villages have access to electricity. Less than 2 per cent in the domestic sector consume gas.

I WOOD

Sri Lanka is a tropical Island and covers an area of 25,332 square miles (65,600 sq. km) or (6.5 million hectares). In 1900 (population 3.5 million), 70 per cent of the land area was under forest cover. In 1953, (population 8.1 million) the forest cover had diminished to 50 per cent. Today (1985 population around 15 million) only 4 million acres or 25 per cent of the land area is under forest cover, (Forest Department - Sri Lanka). The exploitation of our national forests has resulted in rapid deforestation. The Mahaweli scheme also envisages the conversion of 650,000 acres of mainly forest land to irrigated agriculture.

Man made forests began with the plantation of 50 acres of teak in 1800 and in 1976 plantation forests covered an area of about 250,000 acres. This figure is expected to increase to 750,000 acres or 4.6 per cent of the total land area by about 2000 AD, at the present rate of reforestation of about 20,000 acres per annum. The main species used in reforestation in the Dry Zone are teak and eucalyptus, in the Intermediate Zone it is mahogany and in the Wet Montane Zones, pines and eucalyptus. Ipil Ipil is another species introduced lately in the Dry Zone. These species are all exotics and are fast growing. Slow growing indigenous varieties are also planted.

The national requirements of firewood for domestic use have not been accurately assessed. A reasonable estimate of the consumption of firewood or its equivalent is believed to be in the range of 4.3 - 5.2 million cubic metres per annum for the entire Island. A significant amount of material is also obtained from saw mills and waste from coconut plantations and other agricultural residues. Large stocks of firewood are available when forests are cleared for village settlement schemes under the various multipurpose projects. These stocks however, do not reach the cities due to transport difficulties. In the western and south-western areas rubber wood is available from estates taken up for replanting. This wood is brought to Colombo. It is not possible to give a breakdown of the quantities of fuelwood obtained from various sources. It is estimated that the State Timber Corporation supplies around 0.15 million cubic metres. This would mean that a very large part must undoubtedly come from state forests as unrecorded collections.

Besides the demand for domestic use, fuel wood is also used in kilns by a number of industries like the tea, tobacco, brick and tile, lime and bakeries. Timber is also needed in large quantities to operate the 2 plywood factories (Gintota and Salawa) and large quantities are sold (log and sawn) by the State Timber Corporation for building construction purposes. Small quantities are also used in the mining industry. The demand for timber in Sri Lanka is growing very rapidly.

Cooking energy in rural and urban areas is mainly supplied by wood. The excessive exploitation of forests (deforestation) in the island call for the improved utilization of both fuels and cooking devices. In recent years the State Timber Corporation has given considerable attention to the production of charcoal in the country. The use of charcoal will make a considerable reduction in firewood consumption if its use becomes popular with the masses.

2. PETROLEUM

Petroleum resources in Sri Lanka have not been identified up to now. The Ceylon Petroleum Corporation was established in January 1961. It operates a refinery at Sapugaskanda with an installed capacity of 2,300,000 metric tons, a blending plant and a candle factory. Besides other development projects it is also responsible for oil exploration. Excluding firewood, petroleum products are the most important source of energy accounting for the major portion of the total commercial energy consumption in the Island. Table VIII is presented to show the energy consumption in Sri Lanka from 1961 - 1983 and Table IX shows the projected oil products requirements (1980 - 1990).

The price of crude oil has been steadily rising over the years. Sri Lanka has not directly passed the price increases to the consumer. A gallon of super petrol - Rs. 3.18, kerosene Rs. 1.02 and auto diesel Rs. 1.03 in 1962 has risen to petrol Rs. 61.40, kerosene Rs. 29.97 and auto-diesel Rs. 36.98 in 1985. With the increase in crude oil prices from time to time the local selling prices of petroleum products have to be increased. As Sri Lanka has to depend on kerosene (domestic purposes), heavy diesel and furnace oil (industrial sector) and petrol (household sector) the outlook for oil seems very gloomy. Off-shore investigations for petroleum have however, commenced and there is some hope that Sri Lanka may discover oil in the future.

The Gas Company which is State owned is the sole distributor of LPG gas at present. The consumption of LPG gas had reached 8915 MT in 1984 from 543 MT in 1975. The Gas Company has now reached the limit of supplies from the Ceylon Petroleum Corporation.

TABLE VIII

ENERGY CONSUMPTION IN SRI LANKA
1961 - 1983
(In Common Unit of Measure i.e. Gwh.e.r.)

Year	Electricity	%	Oil	%	Coal	%	Total
61	358.0	15.6	1674.6	73.0	261.37	11.4	2293.97
62	382.0	15.6	1809.3	73.8	261.56	10.6	2452.86
63	309.0	12.9	1821.6	75.9	269.06	11.2	2399.66
64	333.0	13.1	1879.5	74.0	327.19	12.9	2539.69
65	360.0	14.5	1860.3	75.1	256.31	10.3	2476.61
66	424.0	16.8	2034.9	80.8	57.94	2.4	2515.94
67	489.0	16.6	2237.4	75.8	229.69	7.6	2551.09
68	556.0	18.8	2319.9	78.5	78.37	2.7	2954.27
69	604.0	19.3	2464.5	79.0	49.68	1.7	3118.18
70	662.0	19.7	2679.0	79.6	22.69	0.7	3363.69
71	722.0	21.5	2612.4	77.7	24.75	0.8	3359.15
72	810.3	22.5	2772.0	76.9	21.57	0.6	3603.86
73	866.1	22.9	2891.4	76.6	18.0	0.5	3775.5
74	982.3	27.9	2295.3	71.7	12.19	0.4	3199.79
75	965.4	30.5	2196.9	69.4	3.75	0.2	3166.05
76	999.3	29.0	2440.8	70.9	1.87	0.1	3441.97
77	1040.6	31.4	2069.8	68.5	1.5	0.1	3311.9
78	1162.3	30.0	2682.3	69.3	24.18	0.7	3868.78
79	1298.3	30.7	2932.1	69.2	4.01	0.1	4234.41
80	1391.6	31.7	2993.8	68.2	5.09	0.1	4390.49
81	1503.1	31.1	3320.7	68.8	3.59	0.1	4827.39
82	1686.0	31.2	3646.8	67.4	77.79	1.4	5410.59
83	2114.4	30.3	4810.86	69.0	40.49	0.6	6965.59

Conversion Factor: 1000 tons of oil = 3 Gigawatt hours
1000 tons of coal = 1.875 Gigawatt hours
1 Million Kwh = 1 Gigawatt hour

Source: Ceylon Electricity Board, Ceylon Petroleum Corporation and Customs Returns.

After: Edwin Ranasinghe - Manager (Economics and Planning) Ceylon Petroleum Corporation.

TABLE IX

PROJECTED OIL PRODUCTS REQUIREMENTS IN SRI LANKA

(1980 - 1990)
(1000 metric tons)

Year	Domestic Kerosene	Industrial (HD & FO)	Transport Auto Diesel	Household Petrol	Total
1980	188.9	156.4	401.4	88.1	840.8
1981	195.2	159.9	428.2	87.3	870.6
1982	201.7	163.7	450.0	86.5	901.9
1983	208.4	167.8	472.9	85.7	934.8
1984	251.3	172.5	497.2	84.8	969.8
1985	222.5	177.4	522.5	84.1	1006.5
1986	229.9	182.5	549.2	83.3	1044.9
1987	237.5	288.4	577.3	82.5	1085.7
1988	245.4	194.6	606.7	81.8	1128.5
1989	253.6	201.3	637.6	81.0	1173.5
1990	262.0	208.7	670.3	80.3	1221.3

After Edwin Ranasinghe Manager (Economics and Planning) Ceylon Petroleum Corporation.

3. ELECTRICITY

The development of electrical power in Sri Lanka has been described; (De Silva 1980). Electricity was introduced to Sri Lanka in 1895 when Colombo was supplied with electricity from diesel engines in the Pettah Power Station. In 1929 the installed capacity was 2.4 MW and the demand was 1.9 MW. The Stanley Power Station was constructed at Kolonnawa in 1929 with an installed capacity of 6 MW which was later increased to 9 MW. A further 3 MW was installed at the Pettah Power Station in 1939 and by this time the system peak demand was 7.8 MW.

The first hydropower station to be constructed was the Laksapana Power Station with an installed capacity of 25 MW and was declared open in 1950. The installed capacity of this station was later increased to 50 MW and the work was completed in 1958. The Kelanitissa thermal station (50 MW) was completed in 1964 and in 1958, the next hydropower station at Norton Bridge (Wimalasurendra Power Station) with an installed capacity of 50 MW was completed. These hydro schemes utilized the water resources of the Kehelgamuwa Oya.

The next phase of development was based on the utilization of water resources of the Maskelioya and the first station was constructed at Polpitiya with an installed capacity of 75 MW. This station was commissioned in 1969. The new Laksapana Power Station (100 MW) was completed in 1974. Work on the Canyon Power Station (30 MW) on the Maskeliya Oya was completed in 1983. By this time other hydropower stations connected to the system were Inginiyagala in 1954 (10 MW) and Uda Walawe (6 MW) in 1968. The power available from these two small stations are seasonal (See Fig. 3). The Chunnakam (diesel) station (8 MW) was installed in 1959. In order to meet the expected energy shortfall in the immediate future, thermal plants with a total capacity of 170 MW have been installed at Kelanitissa and a 80 MW plant has been installed at Sapugaskanda (1984).

The Mahaweli Ganga development scheme will bring under cultivation about 650,000 acres of new lands and provide assured water for another 250,000 acres of existing lands. The Master Plan envisages the construction of 15 reservoirs on the Mahaweli Ganga, its tributories and the Maduru Oya. Eleven of these reservoirs are to include power stations. The total installed capacity of the main stations are assessed at around 500 MW in the Master Plan. It also provides for the future development of a number of hydropower stations in the upper catchment of the river giving an additional installed capacity of nearly 450 MW. The work was to be undertaken in 3 phases each consisting of a number of projects and spread over a period of 30 years.

Work on the first project in the Master Plan, the Polgolla Bowatenne diversion was inaugurated in 1970. The main features of the project are the construction of a dam across the Mahaweli Ganga at Polgolla and the diversion of water through a tunnel (26100 feet in length) to Ukuwela where a power station is operated with an installed capacity of 40 MW. After power generation the water flows to Bowatenne where a reservoir is created including a power station with an installed capacity of 40 MW together with the construction of a tunnel (22900 feet long) to divert part of the waters into the Kandalana - Kalawewa basin. These complexes were completed in 1976 including the power station at Ukuwela and the Bowatenne power station was commissioned in 1981.

In the present (after 1977) accelerated programme of Mahaweli development which is in progress, the State has decided to take up the development of the first stage, to be completed in about 6 years. A number of reservoirs are being constructed with an installed power capacity of over 500 MW and the irrigation development of 320,000 acres of new land and 30,000 acres of existing land. The main reservoirs include Victoria (first stage 210 MW), Kotmale (134 MW) and Randenigala (122 MW). Other reservoirs mentioned are Maduru Oya (8 MW) Moragahakanda (40 MW) and Rantembe (46 MW) See Fig. 3.

The installed capacities and the expected annual energy outputs of the generating stations as at 1985 and power stations under construction and those planned for development under the accelerated programme of Mahaweli development and the Walawe ganga project are presented in Table X. The predicted maximum power demands on the national grid (Ceylon Electricity Board study in 1981) for the period 1984 - 1996 are presented in Table XI.

The total hydropower resources of Sri Lanka (existing and unexploited) as estimated in 1968 are presented in Table XII. As there has been no systematic basin by basin study undertaken so far, figures presented for hydropower resources (Table XII) are subject to revision. The need to investigate all potential hydropower sites so as to examine their technical feasibility and economic viability has been emphasised from time to time. With a study of this nature it would be possible to draw up a Master Plan to develop the hydropower resources on a planned basis. In this connection the Ceylon Electricity Board has plans to carryout a survey of the hydropower potential of the country under a Master Plan study on the subject of energy in Sri Lanka.

TABLE X

SRI LANKA POWER STATIONS

(Existing - under construction - those planned)

Existing Hydro	Power (MW)	Annual Energy Capability (Gwh)
Kotmale	134	-
Victoria	210	-
Old Laxsapana	50	325
Inginiyagala	10	60
Uda Walawe	6	22
Wimalasurendra	50	105
Polpitiya	75	355
New Laxsapana	100	410
Ukuwela	40	220
Bowatenna	40	135
Canyon	30	144

Existing Thermal	Power (MW)	Annual Energy (Gwh)
Sapugaskanda	80	-
Kelanitissa	170	-
Chunnakam	12	30
Pettah	08	02

Under Construction or Planned for Development	Power (MW)	Annual Energy (Gwh)
Randenigala	122	-
Moragahakanda	40	-
Maduruoya	8	-
Rantambe	46	-
Samanalawewa (Walawe ganga)	120	-

CEYLON ELECTRICITY BOARD

Sri Lanka's electrical energy however, will be met mostly by her hydropower resources till about the year 1990. From there onward the development in this source of energy is expected to be slow. The weather pattern in Sri Lanka is believed to be changing. Recurrent droughts have been experienced in recent years. Observations reveal a progressive weakening of the south-west and north-east monsoon. At the moment this condition has not posed any serious problems with hydropower generation.

TABLE XI

PREDICTED MAXIMUM POWER DEMAND ON NATIONAL GRID

YEAR	MAX. LOAD MW.
1984	657
1985	744
1986	808
1987	883
1988	961
1989	1046
1990	1139
1991	1242
1992	1352
1993	1472
1994	1602
1995	1744

CEYLON ELECTRICITY BOARD
(CEB Study in 1981)

TABLE XII

HYDRO POWER RESOURCES OF SRI LANKA
(Includes existing stations)

Location	Capacity (MW)	Average Annual Output (Gwh)
Mahaweli Complex	962	3380
Kelani Ganga	305	1450
Kalu Ganga	135	580
Walawe Ganga	126	680
Jasmin Complex	36	160
Other Minor Rivers	28	40
TOTAL	1592	6260

UNDP - FAO Report 1968
CEYLON ELECTRICITY BOARD

4. PEAT

Peat is used as a fuel in many countries. The largest known deposit of peat in Sri Lanka is in the Muthurajawela swamp, situated on the west coast, north of Colombo. The deposit covers an area of 34 sq km with an average thickness of 4 metres of peat. Investigations by the Geological Survey Department have proved 50 million tons (wet basis) of peat in the area. Actual reserves are much larger. Drying is one of the great problems of peat workings. The peat contains 80 - 90 percent water. This could be reduced to 10 -15 percent by slow drying over a period of 10 - 12 days. Table XIII shows the results obtained for type samples of peat. The material is of a low grade type and the formations are not of a uniform character. The deposits cannot be considered of value until further investigations.

TABLE XIII

CHEMICAL ANALYSES OF MUTHURAJAWELA PEAT

Sample No.	1-A	3-A	8-C	10-E	13-A
Moisture %	78.34	82.22	83.52	79.39	70.69
Ash %	16.95	24.92	11.24	30.46	27.65
Volatile Matter %	56.07	44.01	51.22	42.69	46.25
Nitrogen %	0.855	0.430	0.918	0.701	0.726
Total Sulphur%	4.15	5.08	5.14	4.78	3.56
Fixed Carbon%	26.98	31.07	37.54	26.75	26.00

Ash content - range 10 to 30 percent (Average 20)
Sulphur content - range 1 to 8 percent (Average 5)
Moisture - range 80 to 90 percent
Nitrogen content - less than 1 percent
Geological Survey Department
Colombo 2.

5. URANIUM AND THORIUM MINERALS

Deposits of Uranium have so far not been identified in Sri Lanka. In 1979 an Island wide stream sediment survey was undertaken by the Geological Survey Department with assistance from the International Atomic Energy Agency (IAEA) to identify uranium mineralization. The survey which was continued in 1983 was a reconnaissance type geochemical exploration programme which helped to demarcate areas for future more detailed surveys. The promising areas include the Kalaoya (1), Galgamuwa (2), Polonnaruwa (3), Rukam - Mahaoya (4), Kalmunai (5), Hanguranketa (6), Passara (7) and Rakwana (8) areas. (Personal communication - Jayawardene 1983) See Fig. 4.

These areas are mainly composed of highly metamorphic rocks. Rocks of Jurassic age (shales, sandstone and arkose) are confined to area (1). The average uranium values obtained for the stream sediments are in the region of 30 ppm U_3O_8, however, values of over 300 ppm have also been recorded. Although anomalous areas have been demarcated detailed surveys to identify source rocks, followed by a programme of drilling and sample testing have to be undertaken to detect the presence of uranium ores that are commonly regarded as ore grades. Uranium in hard rock formations should show high values for economic exploitation. In soft rock formations low grade ores could be exploited economically (30 - 500 ppm.). The Geological Survey has plans to carryout follow up work on systematic lines in the field of uranium exploration.

It is believed that thorium utilizing nuclear reactors appears a possibility in the future. This would create a substantial market for thorium when successful thorium thermal and breeder reactors are developed. Thorium is also used in the manufacture of gas mantles, aircraft alloys, refractories and catalysts. In Sri Lanka thorianite and thorite have been found to occur in moderate amounts in the Bambarabotuwa, Maddegama, Niriella, Malwela, Balangoda, Ratnapura and Pelmadulla areas. The best known monazite deposit is located in Kaikawala and Polkotuwa in the beach sands near Induruwa. Monazite also occurs at other points and in the beach mineral sands which are processed at Pulmoddai. Over 300 tons of monazite could be produced per annum in the country. Table XIV is presented to show typical analyses of monazite, thorianite and thorite from Sri Lanka.

TABLE XIV

CHEMICAL ANALYSES OF MONAZITE THORIATITE AND THORITE-SRI LANKA

MONAZITE

Constitutents	Dondra	Ratnapura	Beruwela
Silica SiO_2	-	1.03	1.06
Thoria ThO_2	9.51	10.29	8.65
Ceria C_2O_3	28.70	27.37	27.35
Lanthanum La_2O_3	28.56	30.13	31.08
Yttrium Y_2O_3	1.05	2.14	0.95
Ferric Oxide Fe_2O_3	0.10	0.81	0.15
Alumina Al_2O_3	1.31	0.17	0.78
Lime CaO	0.89	0.41	0.20
Phosphorus pentoxide P_2O_5	28.91	27.67	27.50
Titanium TiO_2	0.05	-	0.15
Total	99.08	100.02	98.41

Geological Survey Department
Colombo 2

THORIANITE AND THORITE

Constituents	Thorianite (Kondurugala)	Thorite (Kondurugala)
ThO_2	76.22	66.26
C_2O_3	8.04	7.18
La_2O_3	-	-
ZrO_2	traces	2.23
UO_3	12.33	0.46
Fe_2O_3	0.35	1.71
PbO	2.87	-
SiO_2	0.12	14.10
CaO	-	0.35
P_2O_5	-	1.20
H_2O	-	6.40
Total	99.93	99.89

(Imperial Institute)
London

6. THERMAL SPRINGS

A survey of hot springs in Sri Lanka has been undertaken Fonseka et al. (1969). At present they cannot be considered as a geothermal resource for power generation. They do not appear to have any direct connection with volcanic activity as in some other parts of the world. For instance Japan has very rich potential reserves of geothermal energy with about 65 active volcanoes. At present Japan's geothermal power generation output amounts to about 250 MW. In Sri Lanka hot springs are mainly located in the eastern parts of the country where dolerite dykes are well exposed (See Fig. 4). Nine springs have been identified and the waters from these springs record a temperature (Table XV) in the range $34^{o}C$ to $55^{o}C$ which is considered fairly low. These hot springs are of no economic value at the moment.

7. OTHER RESOURCES

Other resources include various agriculture wastes such as paddy husk, sawdust, straw and coir dust. Investigations are being carried out on the application of solar energy. Wind mills have been constructed for use in irrigation and for domestic purposes. The production of biogas has been undertaken and the installation of mini hydro power plants are being examined. The production of alcohol for power is also being considered.

TABLE XV

LIST OF THERMAL SPRINGS IN SRI LANKA

Location		DISCHARGE Litres/hr	TEMPERATURE (Centigrade)	TOTAL MINERALISATION grams/Litre
Number	Name			
1	RANKIHIRIYA		-	-
2	KANNIYAI		42	0.220
3	GALWEWA		-	-
4	KAPURELLA	1200 Approximate minimum	55	0.870
5	MAHA OYA		54	0.990
6	MARANGALLA		47	-
7	WAHAWA		-	-
8	KIVULAGAMA		34	0.550
9	MAHAPELESSA		44	6.490

AFTER FONSEKA ET AL (1969)

Recognising the importance of the marine sciences an Oceanography and Survey of Off-shore Area unit has been set up within the newly established National Aquatic Resources Agency (NARA). The establlishment of NARA also satisfies a long felt need for a National Oceanography Institute for Sri Lanka. Work programmes initiated by NARA include hydrographic and oceanographic surveys including geological and geophysical surveys of off-shore areas. Special attention has been given to a study of the Trincomalee off-shore region which includes the Trincomalee Submarine Canyon (Fig. 5). The availability of deep water ranging from 100 to 2,500 metres in close proximity to the coast at Trincomalee and the existence of a suitable temperature gradient gives Trincomalee the ideal conditions for location of Ocean Thermal Energy Conversion (OTEC) systems. Presently studies are underway to obtain further oceanographic data relating to the same. These studies may also throw light on the origin of the eastern mineralized zone (boundary between the Highland Series and Eastern Vijayan) which could be traced as far as Trincomalee (Seruwila copper-magnetite deposit).

FIG: 5 - THE TRINCOMALEE SUBMARINE CANYON PHOTO REPRODUCTION OF PHYSIOGRAPHIC MODEL OF THE CANYON (COURTESY OF THE NATIONAL AQUATIC RESOURCES AGENCY)

SUMMARY

Firewood still remain the most important source of energy in the rural areas, accounting for nearly 60 percent of the Island's energy needs. At present only 25 percent of the country is covered by forests. It is envisaged that plantation forests would cover about 5 percent of the land area by about 2000 AD. Attention has also been givern to the production of charcoal in the country. Sri Lanka is devoid of oil, and crude oil is imported and refined. Limited quantities of coal are imported. The peat occurrences in the Island cannot be considered an energy source. This also applies to the known thermal springs. Monazite occurs in appreciable amounts. Although areas have been demarcated for uranium surveys, much work remains to be done in this field of activity. The total hydropower resources of Sri Lanka were estimated in 1968 for an installed capacity of 1600 MW, (Average annual output - 6260 Gwh). Projects considered to be economically not viable during this period (1968) could be highly viable now with the rise in oil prices. When the Master Plan study (to be undertaken by the Ceylon Electricity Board) on the energy problem is completed a true picture of the hydropower potential in Sri Lanka would be available. The country's electrical energy will mainly be met by her hydropower resources till the late 1990's. According to power demand forecasts for the country the probable demand on the national grid in the year 1990 is around 1140 MW and in 2000 AD, it would be in the region of 2500 MW (9 percent growth rate from 1992). Taking hydropower development to supply 1500 MW by the year 2000 AD the alternative energy requirement is considerable. Revised figures for electrical energy

demand in the near future are bound to show higher values than those mentioned here.

Indications are that if a proper study is undertaken (taking into account the rising prices of fossil fuels and coal) the economically exploitable hydropower potential of the island at present would be in the region of 2500 - 3000 MW. Although this figure (3000 MW) is nearly double the hydropower potential (1600 MW) as estimated in 1968, hydropower development in the country after the turn of the century is expected to be slow. The immediate need therefore is to develop and introduce new sources of energy. Alternative sources of energy such as solar, wind, biogas are not going to solve the large blocks of energy demands in Sri Lanka around 2000 AD. They are mainly acceptable for rural application. Power from coal has to be introduced and even power from nuclear reactors may have to be considered in order to meet the large blocks of energy demands in the near future.

CHAPTER 6

SRI LANKA OPTIONS FOR THE FUTURE

GENERAL STATEMENT

Energy is the fundamental element for the maintenance and development of a national economy and society. For Sri Lanka in particular which is poor in domestic energy resources, the energy problem is a crucially important matter and one that dominates the future of our country. With the steady increase in petroleum products it is essential that Sri Lanka plans for a transition to a lesser dependence on fossil fuels. A wide range of technological options is available to most countries. A few however, may be of actual relevance to them in specific situations as regards their needs, capital cost involved, the absorptive capacity of the population in general and the availability of resources including technological hardware. Much debate now centres around which alternative technologies are most appropriate for the developing countries. In this connection the State has given consideration to examine a broad spectrum of technologies that could be considered as appropriate to be applied in Sri Lanka. A number of organizations in the country are engaged in new energy research, application of known technologies and the study of various other aspects of the subject.

NEW GLOBAL ENERGY SOURCES

There is no doubt whatsoever that petroleum products will continue to play a vital central role in the commercial energy consumption of both the developed and developing countries for many more years. The world up to now has relied upon chemical energy carriers, preferably in the form of liquid fossil fuels for transport purposes. With fossil energy carriers getting scarce, research has been undertaken on alternatives to oil. The use of ethanol (ethyl alcohol) from sugar cane and other sources instead of gasoline is widely used in Brazil in modified automative engines. This raises the question of the use of agricultural land for energy purposes rather than for food crops. The products of coal hydrogenation with respect to transport and storage offer the same advantages as oil. Although coal hydrogenation techniques are not yet economically competitive their development is of long term importance because of the foreseeable shortage of oil. The generation of liquid products from coal (oil from coal) is still being carried out in South Africa, because of the very high price of oil and the abundance of cheap coal in that country. If coal is to be used in large quantities in the future it will also be necessary to render it harmless from the view point of environment pollution. Another possible candidate is hydrogen which has a broad range of possible uses as fuels. Techniques for manufacture, transport, storage, and safe handling of hydrogen are yet to be solved.

Research and development work in the field of alternatives to oil would therefore require considerable studies before they can be perfected. It is by now no surprise that coal proves to be by far the most abundant of the fossil resources sufficient to cover global needs for hundreds of years. Although coal is in abundance the problem would be how it is to be used to satisfy the most pressing component of the demand for fossil fuels - the liquid fuel component.

For the case of nuclear power there is a variety of nuclear technologies which range from existing light water reactors (LWRs) through fission fast breeder reactors which are now been installed to fusion technologies, an area where active research is being undertaken. For fission reactors the resource is natural uranium. With improvements in LWR efficiencies and recycling of spent fuel together with the introduction of breeder reactors capable of using natural uranium that cannot be used directly in LWRs, the world known uranium resources are expected to last for many years beyond 2030. Nuclear reactors for power generation have now been installed in both the developed and developing countries as it is an economic source of energy. Mention has however, been made by concerned scientists of accidents at nuclear power plants which may result in massive radiation poisoning. Statements like these have quarantined nuclear power behind a barrier of fear. The most serious incident in the history of commercial nuclear power generation took place at the Three Mile Island nuclear unit in Harrisburg, Pennsylvania and no serious harm was caused by this incident. Nuclear scientists now believe that the probability of a serious accident threatening any human being is so remote that society can easily afford to live with risks from nuclear power generation. American scientists who conducted a two year study from the American Atomic Energy Commission had concluded that the odds against an American dying from a nuclear power accident are 300 million to one. The most prestigious scientific minds in America after weighing the facts have called for all-out development of nuclear power as it is the most promising of all energy sources now on the horison. At the end of 1980, a total of 253 nuclear power reactors were in operation supplying 8 per cent of the world's electricity (IAEA -- 1982).

Solar power is a more immediate possibility than fusion power. The potential of the hard solar power applications involving large centralised technologies is tremendous. Considering the possibilities of solar plants located in space outside the earth's atmosphere increases the global solar potential even more. Equipment required to collect incoming solar energy is expensive while land availability may not be a problem. Material availability may pose problems. The sun-rich countries (tropical regions) would benefit most from solar technologies some of which have already been perfected.

The conclusion to be drawn from available information is that present day nuclear fission, future development of nuclear fusion, solar technologies and the world's large reserves of coal are the ones that may provide the bases for a future global energy system when oil reserves get gradually exhausted. Other forms of alternative sources of energy for future global use can only play a supplementary role, though by no means an insignificant one.

NEW ENERGY RESEARCH AND DEVELOPMENT IN SRI LANKA

An attempt has been made by the State towards the development of an energy policy for Sri Lanka. The Ceylon Electricity Board, Ceylon Petroleum Corporation, Colombo Gas and Water Co. Ltd., the Forest Department including the State Timber Corporation and the Ministry of Mahaweli Development are the main organizations that are directly connected with the subject of energy in Sri Lanka. There are a series of other institutions administered by a number of Ministries who are also concerned with problems related to energy. There is however, no separate agency to co-ordinate, monitor and plan the demand and supply of the different forms of energy and to promote the efficient use of energy in the industrial and domestic sectors. There is also no effective central body for undertaking research and development on new and renewable sources of energy including the application of known technologies. The National Science Council of Sri Lanka (NSC) which has now been restructured (1982) and named the Natural Resources, Energy and Science Authority (NARESA) is at present the organisation which would co-ordinate all matters pertaining to energy undertaken by various organizations within the country including matters connected with policy.

The main organisations engaged in new energy research and other aspects of energy together with a few of their important activities related to energy are listed below.

1. Natural Resources, Energy and Science Authority (NARESA).

   Co-ordination of activity amongst institutions concerned with matters relating to energy.

   Undertakes feasibility studies on various aspects of energy.

   Funding research activity.

2. Ceylon Institute of Scientific and Industrial Research (CISIR).

   Utilization of organic waste for biogasification.

   Production of ethyl alcohol on a pilot plant scale and improvement of alochol distilleries.

   Efficient production of charcoal.

   Improved cooking stoves (fuelwood - charcoal).

   Adoption and application of known solar technologies.

3. National Engineering Research and Development Centre (NERD Centre).

   Design and development of low cost equipment for mini-hydro electric plants.

   Adaption and application of known solar technologies.

Design and development of an alternative cheap lighting system for rural application (battery, and fluroscent tube).

Improvements in the design of bullock carts, their development and manufacture keeping to traditional requirements.

Design and development of wind mills (power generation - lift irrigation).

Design and development of a gasifier to be used with stationary and mobile prime movers.

Studies on battery operated light vehicles.

Utilization of waste hydrogen.

4. Industrial Development Board (IDB).

Research, development and promotional activities including popularizing of biogas plants.

Briquetting of agricultural waste materials for use as fuel.

Design and development of cheap cooking stoves (firewood-charcoal).

Improvements in the design of bullock carts.

Application of simple solar technologies.

5. Atomic Energy Authority (AEA).

Operation of a radio-isotope centre.

Proposal to set up a nuclear technology centre (experimental reactor, low cost accelerator and other facilities) with a view to prepare the necessary infra structure and man power for the exploitation of nuclear technology including nuclear power reactors.

Funding research activity and organizing advanced courses pertaining to the nuclear sciences at university level.

6. Ceylon Petroleum Corporation (CPC)

Organization responsible for oil exploration in Sri Lanka which is now in progress.

Institution responsible for importing, refining and distributing petroleum products in Sri Lanka.

7. Ceylon Gas and Water Supply Limited (CGWSL).

Sole distributor of L.P. gas purchased from the Ceylon Petroleum Corporation and other sources when necessary.

Studies on peat gasification.

8. Geological Survey Department (GSD).

Systematic surveys to detect uranium mineralization and surveys for thorium minerals.

Studies on peat deposits.

Geophysical surveys in connection with oil exploration.

Studies on thermal springs.

9. Meteorology Department (MD).

Collection of wind data.

Records of duration of sunshine at several stations in Sri Lanka.

10. Ceylon Electricity Board (CEB).

Authority for the generation, transmission and distribution of electricity in the Island.

Application of known solar wind and biogas technologies including research and development activities.

Research on gaseous fuels.

Feasibility studies on the installation of mini-hydro power plants.

Studies on Sri Lanka peat deposits.

Planning with respect to overall energy development in Sri Lanka.

Organization in charge of the Rural Energy Demonstration Centre for the Asian Region (installed at Pattiyapola village) under the aegis of the United National Environmental Programme (UNEP) and the Sri Lanka government.

The project is composed of a wind electrical system, a solar electrical system (partly on thermal power generators and partly on photo-voltaic generators) and a biogas plant. The objective of the project is to demonstrate the technical, economic and social feasibility of harnessing solar, wind and biogas energy to meet the energy needs of a remote village.

The proponents of this system have claimed that if the project is successful it could be introduced in isolated villages in developing countries.

11. Water Resources Board (WRB).

Design, development and manufacture of wind mills at the Wind Energy Unit.

Promotion drive for the plantation of Ipil Ipil.

12. Forest Department (FD).

Development and conservation of the forest resources of the country.

Provide for a sustained supply of timber and fuel wood to meet national needs.

Assess future needs of fuelwood and make plans for raising fuelwood plantations in strategic locations.

13. State Timber Corporation (STC).

Exploitation and marketing of fuelwood from State Forests.

Development of the wood charcoal industry in Sri Lanka.

Application of solar technologies (drying).

14. Ministry of Mahaweli Development (MMD).

Ministry responsible for the first stage programme under the accelerated Mahaweli Development Scheme which also includes the development of reservoir head works with a total installed capacity of nearly 500 MW of power (work is in progress).

15. Ministry of Industries and Scientific Affairs.

Management aspects of energy including the efficient use of energy in the industrial sector.

16. Central Engineering Consultancy Bureau (CECB).

Agency responsible for the various engineering aspects for the Mahaweli Development Programme. Studies on mini-hydro power plants and their installation.

17. Central Agricultural Research Institute - Gannoruwa (CARI).

Application of biogas technologies.

18. Sri Lanka Sugar Corporation (SLSC).

Organization responsible for State sugar cane plantations.

Research and Development work on the utilization of alcohol as a source of power.

Studies on bagasse as a source of energy.

19. Ministry of Local Government, Housing and Construction (MLGHC).

Promote application of solar technologies for rural requirements.

Promote application of wind energy, in rural areas.

Promote biogas production in rural areas.

20. Ministry of Power and Energy.

Institution responsible for energy policy.

Energy management aspects.

Promote application of known technologies.

21. National Livestock Development Board (NLDB).

Agency responsible for the development of livestock in Sri Lanka (Note: Technology for biogas production is known and also reliable particularly where livestock is abundant).

22. National Aquatic Resources Agency (NARA).

Institution charged with the responsibility of carrying out and co-ordinating, research, development and management activities on the subject of aquatic resources (living and non-living resources).

The establishment of NARA also satisfies a long felt need for a National Oceanographic Institution for Sri Lanka.

Assess the ocean energy resource potential around Sri Lanka through the joint efforts of overseas oceanographic institutions and local organisations.

23. University of Sri Jayewardenapura (Nugegoda) – Department of Physics.

Studies on biogas.

Studies on solar energy.

24. University of Jaffna (Botany Department).

Studies on preservation of food materials using gamma irradiation.

Studies on alcohol production.

25. University of Peradeniya (Department of Agricultural Engineering).

Studies to determine the suitability of buffalo breeds for draught.

26. University of Peradeniya (Faculty of Engineering).

Design of biogas digesters and studies on biogas yields.

Studies on turbines.

Studies on wind energy.

27. University of Moratuwa (Department of Mechanical Engineering)

Studies on solar refrigeration, solar cooking, and solar water heating systems.

Studies on other uses of solar energy.

Studies on wind mill pumps.

28. Rubber Research Institute (Ratmalana).

Use of radiation for curing of natural rubber latex.

Use of solar energy for drying crepe rubber.

29. Coconut Research Institute.

Studies on calorific values of coconut components for use as an energy source.

Studies on coconut oil as a fuel source.

30. Sri Lanka School of Agriculture (Angunakolapelessa).

Studies on biogas.

Studies on solar cooking and solar hot water systems.

31. Ceylon Plywood Corporation.

Studies on Ipil Ipil plantations as a source of fuel wood.

32. Private Sector Institutions.

A few private sector organizations are also involved in energy research and development work including introducing known technologies to Sri lanka. The Ceylon Tobacco Company in particular has undertaken R and D work on the efficient use of agricultural wastes for power generation and for other heating purposes.

OPTIONS FOR THE FUTURE

Fossil fuels, mainly oil, gas and coal will still be the main sources of energy until the turn of the century. Coal is the most abundant of the fossil resources and is capable of satisfying global needs for hundreds of years. It is well known now, that Sri Lanka's electrical energy will be met mostly by her hydropower resources till about the late 1990's. Due to the limited potential in this resource after this date the development of hydropower will be slow.

The population by about the year 2000 is expected to be around 20 million. In order to meet the large blocks of energy demands beginning by about the year 1990 an alternative source of energy for electric power generation has to be introduced. According to the growth in the maximum power demand as forecast in 1981 by the Ceylon Electricity Board (see Table XI) the predicted maximum demand on the national grid by 1990 is 1139 MW, and by 1995 is 1774 MW. Electricity projections of the Ceylon Electricity Board (CEB) for the year 2000 is around 2500 MW. (Energy in Gwh - 13500). These projections are based on a 9 per cent growth rate from 1992 onwards. Projections are being revised from time to time and the above mentioned figures may change and they are only useful as a guide.

About half the hydro potential (main reservoirs) of Sri Lanka would have been tapped once the accelerated Mahaweli Programme is completed by the late 1980's. The generating system in Sri Lanka is therefore predominently hydro based with limited thermal support (steam and diesel plants). Thermal plant is usually used to back-up the hydro shortages during periods of low rainfall in reservoir catchment areas and to improve in general the thermal back-up for the present system. At present (1985) about 270 MW of thermal plant is available. Around 1990 alternative sources of power generation would be prohibitively expensive, at this time the only alternatives available are:

1. Coal Plants
II. Nuclear Power Plants

Attention has also been drawn to the necessity of installing in stages a large thermal plant fuelled by imported coal in the range of 1000 MW (250 MW x 4) in the 1990s to meet the base load electricity demand. This author also advocates that while planning for the first 1000 MW power plant provision be made for an extension of a further 1000 MW to utilize all facilities of the first plant, Fernando (1980). The development of alternative energy has to take place in stages, 250 MW at each stage and this should develop to 1000 MW by the year 2000.

Sri Lanka is devoid of coal. If the above proposal is accepted a 250 MW coal plant has to be established at least by 1990. The lead time necessary for a project of this nature is about 10 - 12 years. An agreement to obtain coal supplies, the design of the power plant in the vicinity of a good harbour close to the load centre which is the Colombo region together with information on the prices of coal are areas which should be carefully studied. It is now envisaged that coal plants of arround 250 MW would be added to the system beginning around 1990 (Ceylon Electricity Board). Trincomalee has been mentioned as one of the sites for the establishment of a coal plant.

In 1980 (23-7-1980) cabinet gave approval to a proposal to start a programme of work that would lead to the production of electricity using a nuclear reactor. In power systems it is customary that the largest set has to be within 10 - 15 per cent of the load in the system. In Sri Lanka in about the year 2000 the load in the system is expected to be around 2,500 MW. Ten per cent of this figure is 250 MW. It is said that the economic size of a nuclear power plant today is 600 MW. This would mean that nuclear power has to be ruled out in Sri Lanka in this century. It must however, be remembered that as technology advances smaller nuclear plants may prove econmical in the near future. Whether Sri Lanka goes for nuclear energy or not it is desirable that every effort must be made now to build our own capabilities to handle nuclear power generation. A programme of work in this direction has already been initiated by the Atomic Energy Authority with assistance from the International Atomic Energy Agency (IAEA). In the event that Sri Lanka has no alternative but to install a nuclear reactor for power generation, such training programmes would be extremely useful. In the light of the information available so far it may be mentioned that priority should be given for training at all levels in the field of nuclear technology. This would enable Sri Lankan scientists to handle a power reactor if the need arises by the turn of the century.

Studies which have been undertaken so far indicate that energy of the future is not going to be cheap. The proposal to install thermal plants fuelled with imported coal seems the best answer to meet the energy crisis in connection with electrical power generation in the not too distant future. Very high level priority has also to be given to afforestation bearing in mind that the population of Sri Lanka would be around 20 million in the year 2000 and that over 80 per cent of the present population (15 million - 1985) use firewood for cooking purposes.

Alternative sources like solar, wind and biogas (where the technology is known and proved) should be introduced where possible especially in rural areas.

SUMMARY

Sri Lanka is poor in domestic energy resources. Imported petroleum products will no doubt continue to play a vital central role in the commercial energy consumption of the country for many more years. Even at present, oil is prohibitively expensive especially for power generation. Approaching the year 2000 an alternative source of power generation has to be introduced to meet the large blocks of energy demands. The shortage for an alternative source of energy will start in about 1990. From available information coal and nuclear power are the only sources available to meet the future demands of energy in Sri Lanka.

In power systems the largest set installed has to be within 10 - 15 per cent of the load in the system. Assuming that a 250 MW nuclear power set is considered to be economical in the near future, nuclear power generation in Sri Lanka could only be introduced by the turn of the century when the predicted maximum demand on the national grid is around 2500 MW. The lead time for a project of this nature is 10 - 15 years. Sri Lanka is new to nuclear technology. Every effort should therefore be made to build up local capabilities to handle a nuclear power set in the event Sri Lanka is forced to install a nuclear power plant.

The installation in stages of a large thermal plant (to supply the country's electrical demands) fuelled by imported coal is less complicated and for the present seems more practicable.

Taking into consideration the population increase by the turn of the century the State has no choice but to give the highest priority to afforestation. Other forms of energy sources (solar, wind and biogas) should also be considered for installation in rural areas and in industrial concerns where possible. The energy of the future is not going to be cheap and it is very essential that the efficient use of energy should be encouraged and introduced in all sectors.

CHAPTER 7

SUMMARY AND CONCLUSIONS

Oil resources which are gradually being exhausted are for all practical purposes considered non-renewable. There is usually a large factor of gamble in the search for oil. As oil is an exhaustable resource there is continual search for new areas and development of new oil fields. Experience has also shown that as our geological understanding and our exploration teachniques have improved so has the extent of known oil fields been enlarged. Whether these discoveries are limited or unlimited, would depend on the stock of oil available in the Earth's crust which is unknown to us.

The world up to now has relied upon chemical energy carriers, principally in the form of liquid fossil fuels for transport purposes (gasoline). Although coal is sufficient to cover global needs for hundreds of years, the real problem would be to satisfy the demand for liquid fossil fuels when oil gets gradually exhausted. Oil from coal as produced in South Africa, alcohol (ethanol) from sugar cane as produced in Brazil and studies on the generation of synthetic hydrocarbon fuels and the use of pure hydrogen as a fuel are areas which have attracted attention in recent years. The production of chemical gasoline has also been administrated in Japan. Alternatives to oil would therefore require considerable research and development before they could be perfected. Petroleum products will therefore continue to be the main source of commercial energy (even at prohibitive prices) for many more years after the turn of the century.

Electrical energy in Sri Lanka is met mostly by her hydropower resources. Once the accellerated Mahaweli development programme is completed the better known hydropower potential of the country (the most promising ones) would have become tapped. Thereafter the development of this resource would be slow and an alternative source of power generation has to be introduced. It is well known that the alternatives available include the installation of coal plants or nuclear plants for electrical power generation. Sri Lanka does not posses any capabilities at the moment in the field of nuclear technology. It would therefore be desirable initially to install thermal plants fuelled by imported coal for power generation. Nuclear power may be introduced to Sri Lanka after the turn of the century. It is therefore best that Sri Lanka should first build up her own capabilities and be prepared to handle nuclear power generation in the event the country has to install a nuclear reactor around the year 2000. The Atomic Energy Authority (AEA) has already initiated teaching programmes at University level in areas connected with nuclear sciences.

With the increase in population to nearly 20 million by the year 2000 the demand for fuelwood for cooking purposes would increase very rapidly. It is also unlikely that rural Sri Lanka will switch to an energy source other than firewood for cooking, for many more years. Sri Lanka has therefore to ensure fuelwood supplies through the development of areas earmarked for this purpose and also concentrate on the development of the country's rapidly diminishing forest cover. The State has therefore given the highest priority to develop the country's forest resources through the Forest Departrment by undertaking a long term programme to cover a variety of forestry related areas including the establishment of new plantation forests, tightening of enforcement work relating to timber offences and upgrading of training for foresters including the commencement of a degree course in Forestry at one of the local universities.

The necessity for identifying alternative sources of energy especially for application in rural areas cannot be overlooked. Renewables seem to offer the potential to provide a sustainable energy base for the rural sector of Sri Lanka. The immediate concern of a local programme should be to introduce relatively simple technologies such as the production of biogas, use of wind energy and the maximum use of solar energy where possible. Although these technologies have been introduced into the country much more work has to be undertaken by the various research and other organizations for these technologies to produce results that are useful to people in the rural sector. In addition to making greater use of renewable sources of energy, better use of available energy should also be made. The efficient use of energy in all sectors would lead to substantial savings in energy budgets. Action has already been initiated by NARESA to formulate an energy policy for Sri Lanka. Institutional arrangements should also be streamlined for evolving effective solutions to the energy problem as a whole.

The alternative sources of energy discussed and others which are being studied at present are not going to solve the large blocks of energy requirements in the country by the turn of the century. Sri Lanka will undoubtedly have to take a decision whether to use coal or nuclear power or both for electrical power generation. It must also be remembered that long lead times are usually associated with projects of this nature (10 - 15 years). In this connection areas of interest which have been studied by the Natural Resources, Energy and Science Authority (NARESA) include:

(1) The proposal to use atomic energy for the generation of electric power in Sri Lanka.

(2) The proposal of the Ministry of Agricultural Development and Research for the production of power alcohol and the supply of energy from agro products.

(3) The feasibility of ocean thermal energy conversion (OTEC) power for Sri Lanka. (this is an area which is not of immediate interest to Sri Lanka). However, if a need arises, a prototype OTEC power system could be established off Trincomalee when the required hydrographic and oceanographic surveys proposed by NARA have been undertaken.

(4) Research and Development projects undertaken in Sri Lanka on energy related problems.

The importance of energy to the economy of nations has been underscored repeatedly in recent years. For none is energy of greater consequence than for the people of the developing countries. Sri Lanka is poor in energy resources. Available information on the energy problem facing Sri Lanka indicate that an alternative source of energy has to be introduced for power generation in about 8 to 10 years time. In this connection the Ceylon Electricity Board has already plans to introduce thermal plants to the country fuelled by imported coal, the introduction of nuclear power to Sri Lanka by the turn of the century needs further study.

With the tremendous advances now made in the area of oil prospecting together with the new techniques which are being worked out and perfected for detecting oil deposits including improvements in drilling techniques will undoubtedly result in new oil fields being discovered in hitherto unknown areas and the extent of new discoveries are therefore being enlarged each year. World oil production which is expected to turn downward within the next 25 to 30 years may presumeably not show serious signs of exhaustion taking into consideration new oil discoveries can in fact be made (as has happened during the last decade) the dawn of the so called energy crises which is normally expected 25 to 30 years hence, may probably get considerably delayed. It is then logical to assume that the expected energy crises would then take place towards the middle of the twentyfirst century (2050). It may be said that their is probably no one answer for the energy dilemma of nations poor in energy resources. Finally, it would be interesting to mention the present position regarding the world oil scene. In its prime during the 1970's OPEC alone set the course of the politics and economics of oil. It dictated how much of crude oil should be produced or sold at what price and to whom. But today, oil demand (because of the rising prices and conservation measures) has fallen to its lowest level. With new sources of oil being discovered all the time outside OPEC areas, OPEC finds it cannot set prices any longer. New exporters include Britain, Norway, USSR, Egypt, China, Oman, Zaire, Columbia and Cameroon. Overall production of crude oil by OPEC members is now limited to 17.5 million barrels a day compared with a peak of over 30 million b/d in the late 1970's. In 1973 OPEC accounted for two-thirds of world production of oil. Twelve years later its share was down to two-fifths. During this period non-OPEC production rose by 35 per cent and today non-OPEC countries account for 67 per cent of the immediately available oil in the world according to estimates by the New York based Petroleum Intelligence Weekly. The current oil glut is predicted to run out in 15 years or so, but the oil power of the Arabs will continue as they hold the worlds largest concentration of oil reserves that could outlast any of their competitors.

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