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ENERGY RESOURCES DEVELOPMENT OPPORTUNITIES IN DEVELOPING COUNTRIES, WITH SPECIAL REFERENCE TO LATIN AMERICA*

* Paper prepared by Energy Section, Resources and Transport Division, United Nations.

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I. ENERGY RESOURCES DEVELOPMENT OPPORTUNITIES

With the sharp rise in imported energy prices and the resulting impact, particularly on the balance of payments of the energy-deficit developing countries, attention is now focused on the importance of achieving self-reliance in energy to the extent it is feasible in technical and economic terms, and on the development and utilization of indigenous energy resources. Attempts will be made to widen the available energy options and to provide speedy and effective solutions to the growing energy problems in at least three directions: (1) expanding the conventional energy resource base; (2) developing alternative sources of energy; and (3) making more efficient and economical use of available energy.

Some of the greatest developmental challenges and opportunities lie in the expansion of the resource base of both conventional as well as non-conventional energy sources, particularly in the developing countries. The developing countries have yet to undertake vigorous programmes of exploration for underground energy (oil, coal, oil shale, tar sands, uranium, geothermal energy, etc.) and of utilization of their vast potentials of renewable sources of energy (e.g. hydropower, solar, wind and tidal power). Even the use of only presently available technologies will result in an extraordinary expansion of their energy resource base. It is estimated that at least 50-60 developing countries have either offshore or on-land petroleum potential, 25-30 countries have geothermal potential, an equal number of countries may have oil shale and tar sands potential and perhaps a larger number is estimated to possess coal and lignite potential. There are vast hydropower potentials in developing countries, only a small fraction of which is presently utilized whilst half a dozen countries have tidal power potential. Sea thermal power exploits the temperature differential between surface and deep waters off the coasts of tropical countries. Solar and wind energy are very widely spread. The wide spectrum of rich energy resource potentials awaiting development in developing countries including those of Latin America calls for the development of a variety of technological and investment resources at the national and international levels.

II. ROLE OF ENERGY PLANNING IN DEVELOPMENT

Heretofore, the development of the primary energy resources of developing countries has been largely haphazard and unplanned, in the sense that most Governments in these countries have not consciously tried to evaluate their energy resources, and develop them in a rational manner, consistent with the needs of the economy. In many cases primary energy resources have been developed by foreign capital for export and any benefits to the host country have been somewhat incidental to the primary objectives of the developers.

The recent rise in prices of crude oil on the international market has reinforced the need for energy planning as an integral part of national development plans.

The main requirements for energy resources development planning are as follows:

1) A knowledge of the extent, nature and quality of indigenous energy resources.
2) A detailed knowledge of existing demand for primary and secondary energy, by type, end-use and sector of the economy.
3) A forecast of the increase in demand for energy, obtained by analysing the development plan, growth of population and other relevant material.
4) Assessment of comparative costs of alternative sources of energy, domestic as well as imported.
5) Evaluation of investment and foreign exchange requirements of meeting future energy needs.

Once the basic parameters for an energy plan have been evaluated, a balance must be struck between indigenous supplies and imports or exports in the case of countries exporting primary fuels.

It is essential that energy planning be organized on a continuing basis. Forecasts should be prepared on a short-term, medium-term, and long-term basis of the order of say two, five, and 15 years respectively. The longer the span of the forecast, the more likely it is to be erroneous and these forecasts must, therefore, be revised on an annual or biennial basis, which in turn implies a nucleus of trained personnel permanently engaged in this work.

Energy is a fundamental factor in development and yet is the one most ignored by conventional planning exercises. It is therefore important that energy planning is given its proper place in policy-making.

III. AN IMMEDIATE ENERGY RESOURCE: BETTER ECONOMY AND EFFICIENCY IN THE PRODUCTION, TRANSPORT AND UTILIZATION OF ENERGY*

Apart from strenuous efforts to increase available primary energy resources, it is imperative that primary energy consumption should be made more efficient, in order to develop a rational energy economy, and maintain a well balanced energy supply system at continuously increasing levels.

Methods of energy conservation and efficient energy usage are of critical importance in the short as well as long-run time periods. The present methods of electricity generation have an inherently low efficiency due to technically almost inevitable conversion losses and dissipation of waste heat. Conventional processes of oil extraction yield only a fraction, with nearly two-thirds of it left underground. With the rise in oil prices, secondary and tertiary methods of recovery will substantially increase the efficiency of oil extraction. In transportation, the overall efficiency in fuel utilization in the present internal combustion engine is not more than 15 per cent. It appears that the development of chemical systems such as batteries and fuel cells might raise the efficiency rate by a factor of three. In the industrial sector, technological progress has substantially reduced the input requirements of energy particularly in such energy intensive industries as aluminium, steel, chemicals, cement, etc. The utilization of energy emitted as a by-product in industrial processes could result in very significant savings of energy. Considerable technological advances have been made in reducing losses in electricity transmission and in oil, natural gas and coal transportation.

The overall efficiency of energy utilization integrates the effects of all efficiencies in the energy processes of the conversion and transporting chains between the demand for net usable energy and the primary energy spent for that purpose; i.e. it represents the ratio between the net energy output and the primary energy input. The overall efficiency of energy utilization varies between 20-50 per cent for different countries and probably averages some 30-35 per cent for the world.

It is almost impossible in the present changing energy situation to make acceptable predictions of possible future energy savings. These will be conditioned not only by progress in technology management and the spirit of co-operation, but

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*United Nations Secretariat, "Consideration of Possible Improvements in the Conversion and Use of Energy", 9th World Energy Conference, 1974.

also by the level at which energy prices finally stabilize and the extent to which energy demand responds to price. However, a rough assessment, taking into consideration the geographical distribution, the prospective evolution and different conservation potentials in various developed and developing countries, would indicate a margin of 10-15 per cent on a short-term basis, 20-25 per cent in the medium-term (1985) and possibly 35-40 per cent for the year 2000.

As far as practical approaches, especially for developing countries, are concerned, a three phase programme for gradually improving the efficiency and economy in energy utilization should be envisaged:

- in the short term where energy savings would result as immediate additional energy made available or correspondingly would reduce costly petroleum imports, attention should be concentrated on determining and meeting the real needs of end-energy forms. Practically little new equipment is involved in this phase in which the accent is mainly on managerial and organizational measures, aimed to limit energy consumption to real needs and avoid all wastage and profligate consumption. Accordingly, domestic, commercial and industrial fuel and electricity demand should be scrutinized and needs for transportation thoroughly reviewed.

- the medium term approach while continuing the previous objectives, would aim at installing only new energy equipment with improved performances, exchange obsolete equipment of low efficiency with better more modern equipment (burners, boilers, furnaces, motors and engines) and prepare for the more comprehensive long-term conservation actions.

- the long term basic approach should encompass an early planned campaign for improving the overall efficiency and economy of energy utilization by:

a) an early attempt to formulate alternative concepts for the overall energy development of developing countries. These concepts should certainly include a careful evaluation of the real needs for energy in the different main consuming sectors, on the basis of the desirable energy-intensiveness of the various processes involved and the available manpower. The special conditions relating to optimal agricultural development together with the possibilities of utilizing local unconventional energy resources are important supplementary factors affecting the conditions under which energy may be saved.

b) securing a more efficient utilization of energy in industry by a high degree of waste heat recovery in technologies where large quantitites of heat result as secondary energy resources, as for example in the iron and steel, chemical and petrochemical, pulp and paper, or some food and textile industries.

c) by meeting electricity and concentrated local heat demand, with jointly produced electricity and steam (or hot water) from combined heat and power stations using a centralized distribution system. Practically all the above-mentioned industries can fit into such a complex system, if above a minimum size or when conveniently located. A good example of such usage is afforded by the fish-meal factories in the south Chimbote area (Peru).

IV. EXPLORATION AND EVALUATION OF INDIGENOUS FOSSIL FUELS

1. Oil and Natural Gas

Many developing countries have yet to undertake vigorous programmes of exploration for oil and natural gas. Even with the use of only presently available technologies, it is estimated that about fifty to sixty developing countries have impressive offshore or on-land petroleum potential (ultimate recoverable resources of petroleum). For example, there are at least seven countries with a range of potential petroleum resources falling between 100 billion barrels to a trillion barrels. These may be called the potential giant oil producers. Nineteen developing countries have very large petroleum potentials ranging from 10 billion to 100 billion barrels. It is estimated that 31 developing countries may have substantial potential resources in the range of one billion to ten billion barrels. In addition, there are 15 countries with comparatively modest petroleum resources ranging from 100 million to one billion barrels. There are a number of other developing countries which have small to smaller size petroleum resources potential.* Till now only a small fraction of these have been developed and herein lies the future opportunities which these countries would wish to exploit, particularly in view of the sharp rise in the price of imported oil.

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* Summary of Petroleum and Mineral Statistics for 120 countries (U.S. Geological Paper 817).

Large tract areas in many developing countries consist of sedimentary basins which await land and aerial surveys for oil and gas exploration. For example, oil discoveries in the Amazonas basin areas of Colombia, Ecuador and Peru indicate similar potentials on the Brazilian side as well. In some instances, in spite of requisite surveys, exploration has not led to any significant discoveries of hydrocarbons. This does not, however, exclude the possibility of discovering petroleum and gas deposits if drilling were to be undertaken at depths beyond the 10,000 to 14,000 foot range; in fact, experience has shown that the incremental increases in costs of deeper drilling have been offset by sizeable discoveries of petroleum in areas where success had not been encountered at shallower depths. Because of the high costs involved, it may be worthwhile to examine the prospects for joint surveying and exploration of certain sedimentary areas common to a region, in search of oil and gas. Such prospects exist with respect to both on-land and offshore areas in Latin America as well as Central and South Eastern parts of Asia.

There are a number of developing countries, apart from the well-known producers and exporters of oil (e.g. Venezuela) which have either limited oil production, insufficient for their own needs, or indications of the possible existence of oil. They may be expected to intensify the search for oil in their territories. Among these may be cited Argentina, Chile, Costa Rica, Peru and Uruguay in addition to Bolivia, Colombia, Ecuador and Mexico.

An oil exploration programme has been carried out off the coast of Central Chile in the area of the Aranco Peninsula by the Chilean state oil company Empresa Nacional de Petroleos, with assistance from the United Nations. First, an airborne magnetometer survey was made in 1970 over the continental shelf, using a modern high sensitivity magnetometer with digital recording. This established the existence of a sedimentary basin and was followed in 1971 by a reflection seismic survey which indicated the presence of a number of favourable geological structures. Drilling was carried out in 1972 and resulted in the discovery of accumulation of natural gas. Despite the fact that no exploitable accumulation was discovered in the first drilling programme, the results were sufficiently encouraging to justify further exploration.

To give some idea of the scale of costs involved in the type of exploration programme described above, the approximate overall costs of the various stages were as follows:

Airborne magnetometer survey (10,000 line kilometers)	US $170,000
Marine seismic survey (4,600 line kilometers)	US $800,000
Drilling (6 wells varying in depth from 750 meters to 3,000 meters in water-depths 60-100 metres)	US $ 10,000,000
Production facilities (estimated)	US $ 70,000,000

The above figures relate to past work, and subsequent inflation would substantially increase the sums required to carry out the same work at the present time.

Exploration and capital expenditures for discovering and developing capacity for the the production of a barrel of oil vary from one country to another and from one location to another in the same country. During the proceedings of the United Nations Ad Hoc Panel of Experts on Projections of Demand and Supply of Crude Petroleum and Products (New York, 9-18 March 1971), one specialist from an internationally integrated oil company submitted data which indicated that exploration and development expenditures for a barrel of oil per day capacity varied between $156 and $830.* Similarly a recent discovery of oil offshore in a developing country has cost $25 million in exploration and will cost another $25 million for development for a production of 25,000 barrels per day by 1975. This would indicate exploration and development expenditure of $2,000 per barrel per day capacity. Investment costs of over $3,000 have been reported in the North Sea, where offshore conditions are among the most difficult in the world.

*United Nations, Petroleum in the 1970s, New York, 1974, p. 32
Sales No. E.74.II.A.1

The following table gives the order of magnitude of investment and production costs (including exploration and lifting) for some of the oil-bearing regions of the world.

TABLE 1*

APPROXIMATE COSTS OF PRODUCING CRUDE OIL OR ITS ENERGY EQUIVALENT

1972-1973

Energy Source	Capital Cost ($/(bbl/day)	Production Cost ($/bbl)
Persian Gulf	100-300	0.10-0.20
Nigeria	600-800	0.40-0.60
Venezuela,# Far East, Australia	700-1,000	0.40-0.60
North Sea, most other Europe	2,500-4,000	0.90-2.00
Large deep-sea reservoirs	over 3,000?	2.00- ?
New U.S. reservoirs (not too remote)	3,000-4,000	1.70-2.50

Natural gas has been extensively utilized in Argentina and Venezuela, and to some extent in Colombia. The pipeline network of Gas del Estado in Argentina is the largest in Latin America, bringing gas to Buenos Aires from as far away as Patagonia and Bolivia. At present, a considerable amount of associated gas is still wasted by flaring although less than in the past and in view of the value of this resource it is recommended that Governments should take active steps to encourage conservation or utilization of the gas. In this respect Argentina, Chile and Venezuela have all taken positive steps to avoid such waste, either by compressing the gas and transporting it by pipeline to the nearest market, or by reinjecting it into underground reservoirs.

Excluding heavy oils.

* Amory B. Lovins: "World Energy Strategies", Bulletin of Atomic Scientists, May 1974.

2. Coal

The majority of coal bearing areas in the world are probably already known, but one cannot discount the possibility that further exploration in developing countries may discover hidden coalfields. It is also true that exploration of many known coal-bearing areas is far from complete, and therefore additional reserves may be discovered as a result of intensified exploration.

Quoted figures of reserves of coal in any given area tend to fall into two main categories, namely; geological estimates of total coal in place and estimates of the mineable reserves which can be recovered at a given price level. Both may vary with time; the former as a result of further geological work, which may have the effect of increasing or decreasing earlier figures as a result of more detailed knowledge; the second will vary in accordance with fluctuations in the price of possible alternative fuels, and also possibly to some extent as a result of changing technology. Since coal mining is labour intensive, changes in the rates of pay for labour will also affect the estimate of recoverable reserves. As an example of the foregoing, the recent sudden increase in the price of fuel oil, which is the principal fuel competing with coal, has rendered viable many coal-mining operations which were formerly regarded as uneconomic. This will have a marked effect on estimates of recoverable coal reserves in many areas.

Cost levels are highly variable and only orders of magnitude can be given. For example, the geological investigation and establishment of reserves for a medium-sized mine producing 1,000 to 2,000 tons/day may cost around $1,000,000, the feasibility study $100,000, and opening and equipping the mine some $5 to $10 million . It must again be emphasized that these figures represent only orders of magnitude, and take no account of inflationary increases of cost with the passage of time. Some allowance for environmental factors must also be made in view of the present worldwide concern. Strip or open-cast mining of coal, in particular, requires quite expensive remedial action if the land-surface is to be restored to anything resembling its previous form and productivity.

Developing countries which are known to have substantial reserves of coal include the following: Botswana, Brazil, Colombia, India, Indonesia, Madagascar, Nigeria, Peru, Swaziland and Zambia. Many others are known to possess minor reserves which may nevertheless make a significant contribution to their economies if developed and utilized.

The exploitation of existing coal deposits even if some of them are not of very high calorific value, together with the introduction of modern mining methods, should be considered as among the main targets during the period 1975-1984 for ensuring the independence of those of the Latin American countries which depend heavily on imports for meeting their electricity needs. An increase in the utilization of local coal is possible not only in Colombia, but also in Argentina, Chile and Peru, as well as in Brazil and Mexico.

Generally speaking, little is known about the coalfields of Latin America and what is known about coal reserves can hardly be summarized. According to data pertaining to coal reserves in some major countries in Latin America, more than 40,000 millions tons of coal exist in probable and proven reserves, equivalent to at least an order of magnitude of 100,000 Twh of electric energy.

3. Oil Shale

Oil shale, despite its name, does not contain free oil. It is an argillaceous, sometimes calcareous, sedimentary rock containing varying proportions of organic matter in the form of kerogen, which breaks down on heating to give a substance resembling crude oil. The kerogen organic content of oil shales can vary from near zero up to around 20 per cent by weight for a rich shale. In addition to being a potential source of oil, oil shale may also be regarded as a low-grade mineral fuel which can be burned directly for steam raising in a suitably constructed furnace. The total known reserve of oil in oil shales is very large, but until recently it has not been economic to extract it in the face of low prices for conventional crude oil but recent increases in oil prices have changed this situation. In fact, the only large-scale exploitation at present, as far as is known, is in the Estonian Republic of the USSR. Formerly, oil shales were exploited in France, Germany, Nova Scotia, Scotland and Sweden, among other places. Pilot plants are reported from Brazil and the western United States. The technology of the extraction of oil from oil shale is therefore well known, but until recently the economics were unattractive.

The problems connected with the exploitation of oil shale are concerned with mining the shale, retorting it to extract the oil, disposing of the spent shale, and transporting the oil to market. Because of its low organic content, oil shales must be processed and the oil extracted at the mine if excessive transport costs are to be avoided. In many cases the oil produced is waxy and must be partly refined before transport. There are also problems involved in crushing and retorting the shale. All these factors add to the cost of producing oil from shale and are among the reasons why exploitation at the present time is not on a large scale.

It is difficult to say exactly how much oil shale development might cost. The geological exploration and sampling phase is slow, but not particularly costly. However, by the time a mine has been put in operation, retorts constructed, processing plant erected, and a pipeline laid, costs are likely to be of the order of \$50 million for a medium sized operation producing, say 1,000 tons of oil per day. Even an operation on this scale would imply mining some 8,000 to 10,000 tons per day of shale and the disposal of a corresponding quantity of shale waste.

Developing countries known to have large oil shale reserves are Brazil, Thailand and Zaire. Many other developing countries are known to have smaller reserves which have never been fully evaluated.

4. Tar Sands

These are sands impregnated with a heavy viscous oil which may constitute up to 18 per cent by weight of the sands. Such sands are known to be widely distributed in the world, occurring in Albania, Canada, Colombia, Ecuador, Ghana, Ivory Coast, Malagasy, Nigeria, Peru, Trinidad, USA, and Zaire. At present only one large plant is extracting oil from such sands, at Athabasca in western Canada. The sand is mined in an open pit and the oil extracted by washing with hot water. At normal temperatures the oil is too viscous to flow and so the extraction plant incorporates a refinery with cracking and hydrogenating facilities. Elsewhere in western Canada, experiments are going on to find a method of extracting oil from the sands where these are too deeply buried to permit mining the sand. Most of the techniques involve heating the oil by injecting steam into the sand, or by setting fire to it, through wells drilled into it. The oil is subsequently produced from the injection wells.

Costs of the plant in Canada have been adversely affected by the remote location and the very severe climatic conditions, but it is estimated that production costs were around \$5-\$6 per barrel of synthetic crude oil produced. The product is of high quality, very low in sulphur. Comparable costs could be achieved, even in developing countries, because with the higher ambient temperature, costs would be lower. It is also possible that exploitation could commence with a relatively simple and unsophisticated plant, provided that some means of transporting the product to market were available.

V. HYDRO-POWER AND NON-CONVENTIONAL SOURCES

1. Hydro-power

Some of the greatest opportunities for developing countries lie in the exploitation of their vast hydro power potential. It is estimated that less than five per cent of the existing hydro power potential has been actually exploited in these countries. Some of the largest unexploited hydro power sites in the world are located in the Mekong-Salween, Brahmaputra and other Himalayan Rivers in Asia, the Congo and other rivers in Africa and in the Amazonas and La Plata basins in Latin America. The comparatively large size of many of these sites and the heavy investments required by way of dams and generating facilities, in relation to the size of local markets have impeded development of such resources. In the future, however, with the growth in electricity demand which is doubling every seven years and with increased regional co-operation in the development of energy resources, it is quite likely that the pace of hydro electric exploitation will accelerate. Even with a substantial increase in local electricity demand, the countries having such potential will only be able to absorb a very limited fraction of these resources for their domestic use. There is here substantial scope for increased inter-country, regional and interregional co-operation requiring the linkage of investment fund, technical assistance and connexions with power markets.

It is clear from the outset that the volume of the Latin American hydro electric potential is tremendous in view of the hydro-meteorological and, particularly, the topographical features of the whole region. The gross surface potential from precipitation, although of a wholly theoretical value, amounts to a regional total of 40,700 Twh per annum, corresponding to a mean of 2 Gwh per square kilometre and an allocation of 138 Mwh per person. The economic potential would be considerably less than this theoretical figure and under certain assumptions this potential has been estimated at 2,800 Twh. By dividing this figure by 8,760 hrs., it is apparent that the mean power potential would be 319 GW.

Out of the total mean power potential of 319 GW, the comparable installed capacity at the end of 1972 (calculated with a utilization factor of 0.5) was only 10.7 GW, corresponding to a utilization of only 3.35 per cent of the potential.

According to published plans, the generating capacity of the new hydro-electric plans which have been approved or were in an advanced stage of consideration in Latin America, totalled roughly 30 GW in 1973. (In a few cases these projects will not be completed before 1984). The recent increase in the price of fuel oil will lead to a reassessment of many potential hydro-electric projects which have hitherto been regarded as uneconomic. In these circumstances it is anticipated that there will be a considerable upsurge in the construction of new hydro-electric schemes.

2. Nuclear Energy

One of the most important non-conventional sources of energy which has started to play an increasing role in the production of electricity is nuclear fission. If it could be consumed in its entirety, a single kilogramme of fissionable material could produce as much energy as the equivalent of 2,000 tons of petroleum (8 Gwh).

Even with current techniques, utilizing but one-hundredth of the potential energy, the fuel transport costs become relatively insignificant, despite the elaborate precautions involved in handling nuclear material. Hence unlike hydro electric plants which can only be built in certain places, nuclear plants can be located closer to the centres of consumption, subject to factors affecting public safety.

Experience has shown that certain conditions must be fulfilled before nuclear electric power can be produced at competitive prices. Above all, the power station must be of a large size. The cost of installing nuclear power capacity decreases faster in relation to the size of the nuclear plants than for conventional thermoelectric plants. The investment cost per kw installed in nuclear power plants equipped with reactors using enriched uranium drops by more than half as capacity is increased from 50 to 300 MWe and by two-thirds when it approached 1,000 MWe. In the case of reactors using natural uranium, the economy of scale is even greater.

Hitherto, it has been necessary to design nuclear power plant in large sizes in order to reap the benefits of the resulting economies of scale which would make them economically competitive. However, the recent quadrupling of the price of oil has meant that nuclear power stations can be economically competitive with oil-fired alternatives at smaller sizes where such units are commercially available. However, it should be borne in mind that from an operational point of view the largest size of generating unit which can be accommodated on an interconnected electricity system is a function of the system size. Since the unit size must not form too large a proportion of the total interconnected system capacity, nuclear power units which can still not be produced economically in very small sizes are not applicable to the small electricity networks found in most developing countries.

Although considerable experience exists in developed countries on the operation of nuclear power stations, there have been problems associated with delays in construction and there is still in some countries no general agreement on the question of plant operational safety.

In addition, as nuclear power plants need greater unit investment than conventional thermoelectric plants, they must operate at a high load factor in order to compete with other sources of electricity generation.

Finally, the possibility of installing nuclear power plants becomes attractive when local energy resources are small or non-existent and, in such cases, only when the demand for electric energy is sufficiently large and cannot be economically supplied from other sources.

3. Geothermal Energy*

Geothermal energy is the natural heat of the earth, usually extracted in the form of hot water or steam. Geothermal activity is widely distributed in the volcanic areas of the world, notably the Andean mountain chain, the African Rift system, and the island chains in the Pacific. The hyperthermal manifestations of the volcanic zones are increasingly being investigated as a source of electrical

* "Geothermal Energy and Its Uses", a paper by UN Secretariat to the Ninth World Energy Conference, Detroit, 1974

power and process heat. The pioneer countries in the application of geothermal heat were Italy, Iceland, New Zealand, and the USA. Subsequently, investigations have been undertaken in Chile, El Salvador, Kenya, Mexico, Nicaragua, Philippines and Turkey, most of these with the active assistance of the United Nations. The physical manifestations which may indicate the presence of industrially exploitable geothermal resources are steam fumaroles, boiling springs or mud pools and steaming ground.

The preliminary exploration consists of geological and geochemical reconnaissance, followed by geophysical investigations, usually in the form of electrical resistivity surveys. Electrical resistivity anomalies may have to be checked by drilling shallow wells to measure the temperature gradient before choosing the sites for exploratory wells. These latter are drilled with modified oilfield rotary equipment to depths of three to four thousand feet, although economic production is frequently found at shallower depths. Reservoir temperatures in excess of 200° Celsius are normal, and the wells may flow naturally at very high rates. The wells usually produce a mixture of saturated steam and boiling water, although in exceptional cases such as at Larderello in Italy and the Geysers in USA they may produce dry steam. The productivity of a well is often as much as 300 to 400 tons of fluid per hour of which 10 per cent to 15 per cent may be steam, at a wellhead pressure of around 100 psig.

Geothermal energy may be used for electricity generation or as process heat in any industry requiring large quantities of low-grade heat. Examples are pulp and paper making and food processing. The principal advantage of geothermal heat over more conventional sources is its extreme cheapness once the exploratory costs have been amortized. This advantage will be accentuated by the recent steep rise in the price of conventional fuels. Among the negative aspects of geothermal energy are the corrosive properties of geothermal brines and problems of waste brine disposal.

Almost all the countries in Latin America have prospects for geothermal resources and there are several known sites which are especially suitable for the establishment of power plants using geothermal energy.

Besides power stations existing in Mexico, other sites in North and Central Latin America (Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama) have a geothermal potential for electricity production as well as countries of the Western Seaboard and the Andean Cordillera (Argentina, Bolivia, Chile, Colombia, Ecuador, Peru, Venezuela) and some Caribbean islands.

Following a successful United Nations-assisted geothermal exploration project in El Salvador, the government is building a geothermal power station of 30 MW capacity. It is hoped to install a further 60 MW of geothermal power plant by 1977 and thereby obviate the need for the one million barrels of oil which are at present imported annually for electricity generation.

4. Solar, Tidal and Wind Energy

Solar energy is at present being utilized in many small installations mostly in the sunnier parts of the world for domestic water heating, domestic space heating and production of fresh water from brackish and saline water. In favourable climates, both domestic hot water systems and solar stills for fresh water have proven successful, technically and in some instances economically. New and innovative approaches for generating electrical energy from solar heat and storage of such electricity are in the process of development.

Tidal energy, where electricity is generated by making use of tidal differences in water levels, could eventually find some applications in Latin America. Suitable sites exist in Argentina and Brazil.

The use of wind energy is widespread in different countries of the world for small-scale electricity generation and for direct pumping from wells. Wind energy may be harnessed, on a small scale, in several places in Latin American countries where wind conditions are favourable, especially in rural areas for its localized use. Before any development of this type is undertaken, areas with suitable wind conditions must be located and detailed meteorological data compiled (wind speeds, duration, etc.)

VI. NON-COMMERCIAL FUELS AND RURAL ENERGY ECONOMY

In many developing countries a significant amount of energy is provided by the utilization of non-commercial fuels which do not normally enter the local energy markets. Of these fuels the two most important are wood and dried animal dung, whilst waste vegetable matter is also used and is illustrated by the utilization of bagasse which can be found in areas growing sugar cane. The efficiency of utilization of these fuels is often extremely low as when wood and dung are burnt in open fireplaces. In addition, their use is frequently accompanied by undesirable side effects such as loss of valuable manure where dung is burnt and deforestation accompanied by soil erosion where wood is used. Fumes and smoke which result from the poor combustion conditions may also give rise to health and fire problems.

Considerable thought is being given to the possibility of supplying the energy needs of rural communities from indigenous renewable energy sources. This concept involves the application of known and well-tried technologies to conditions in the rural environment. Such an integrated rural energy economy would utilize solar energy for providing hot water, wind power for pumping water and possibly producing electricity. Animal dung, previously burnt as fuel, would be digested in anaerobic fermentation plants to produce methane gas for cooking, heating and lighting. The resulting sludge from the digester plant would form a valuable organic fertilizer for agricultural purposes and thus reduce the need to import chemical fertilizers.

The philosophy of supplying rural energy needs from local energy sources is relevant to all developing countries in the present conditions of high energy costs and any effort and money spent on developing suitable systems could be easily justified.

VII. COMPARATIVE COSTS OF ALTERNATIVE ENERGY SOURCES AND TECHNOLOGIES

The foregoing brief assessment indicates that in the present conditions of high oil prices, planning in the energy field is of paramount importance to developing countries. Particular attention needs to be paid to the possibilities for the development of indigenous energy resources and the degree to which these may be substituted for expensive imported oil. Any consideration of the development of domestic energy resources would involve the magnitude of reserves, exploitation costs (both capital and operational), plant lead times and the availability of substitute sources of energy at various price levels.

In regard to the magnitudes of mineral fuel resources, it must be emphasized that the concept of reserves, as commonly used, is geared to a given price level and therefore with the sharp rise in oil prices, estimates of these reserves are likely to be revised substantially upward, since what were considered as marginal or sub-marginal deposits now become quite economic to exploit under the new price regime obtaining since early 1974.

It is also important to recognize the time scale involved in the development of energy resources; for example, the time required to explore and develop oil production may be as long as ten years from the commencement of an exploration programme, particularly if offshore operations are involved, and in any event is unlikely to be less than five years. The exploration and development of a geothermal field also takes around five years. To open a new coal mine may take two to four years depending on the availability of geological information, the accessibility of the deposit and the existence or otherwise of a trained work-force. In regard to nuclear power stations, it may take as long as 8 to 10 years to have it planned, constructed and functioning satisfactorily.

Although the figures given in Table 2 do not refer to conditions in Latin America they provide an indication of comparative costs which were applicable to the United States at the end of 1972. It will be seen from these figures that the average cost of generating electricity from geothermal energy was approximately U.S. 9 mills/Kwh compared with an oil-fired alternative of U.S. 13.2 mills/Kwh.

Table 3 lists the various new energy technologies which are under active development as sources of oil production. The estimated timing of demonstration plants for the various processes together with the projected U.S. production in 1985 give an indication of the significance which each of these may attain in meeting oil needs. The cost of oil derived from these alternatives is estimated to range from U.S. \$5 to \$10 per barrel and thus appears competitive with the present cost of imported oil.

Generally speaking, increased oil import costs are likely to accelerate the pace of exploration for indigenous energy resources in the developing importing countries. Where oil prospects may seem unpromising, efforts will be made to develop alternate sources such as nuclear, geothermal or coal. New investments are likely to be made in alternate sources of energy. These new investments will, of course, compete with other investments and decision-makers will have difficult choices to make. Furthermore, the development of alternate energy sources is a long-term process (usually taking from 5 to 10 years). It is within this context (time-scale); alternate investment costs) that the energy problems of the developing countries, including Latin American countries, must be seen.

TABLE 2

COMPARATIVE COST OF ALTERNATIVE ELECTRIC POWER GENERATION METHODS

Alternative Electric Power Generating Fuels in the United States

Item	Coal 1/	Geothermal Steam Purchased 2/	Geothermal Steam Owned 3/	Natural Gas 4/	Nuclear 5/	Oil 4/
Without Cooling Towers						
Plant Investment ($/Kw)	$213	$180	$260	$145	$345	$145
Plant Factor (%) 6/	60%	75%	75%	60%	68%	60%
Capacity Cost (mills/Kwh)	6.7	4.9	7.0	4.5	9.6	4.6
Fuel Cost (mills/Kwh)	2.8	2.4	-	3.8	2.6	7.9
Operation and Maintenance (mills/Kwh) 6/	0.9	1.0	1.5	0.7	1.7	0.7
Variable Cost (mills/Kwh)	3.7	3.4	1.5	4.5	4.3	8.6
Total Cost (mills/Kwh)	10.4	8.3	8.5	9.0	13.9	13.2
Water Disposal (mills/Kwh)	-	0.5	0.5	-	-	-
Total Cost (mills/Kwh)	10.4	8.8	9.0	9.0	13.9	13.2
With Cooling Towers						
Wet Cooling						
Plant Investment ($/Kw)	$222			$154	$354	$154
Capacity Cost (mills/Kwh)	7.0			4.8	9.9	4.9
Total Cost (mills/Kwh)	10.7			9.3	14.2	8.6
Dry Cooling						
Plant Investment	$241			$173	$375	$173
Capacity Cost (mills/Kw)	7.6			5.3	10.5	5.5
Total Cost (mills/Kwh)	11.3			9.8	14.3	14.1

1/ Plant investment without water cooling derived as an average of base load plant costs for Colorado Public Service Co. escalated at 5% annually from 1966-72. Fuel cost based on price paid by CPS in 1972 for coal containing 1% S or less; heat rate of 10,417 Btu/Kwh computed as a weighted average for CPS base load plants.

2/ Based on PG&E experience at the Geysers adjusted to 1972 as required.

3/ Based on data from the U.N. Informal Seminar on Geothermal Energy, January 1973.

4/ Plant investment without water cooling derived as an average offbase load plant costs for Pacific Gas and Electric escalated at 5% annually from 1966-72. Fuel cost based on price paid by PG&E in 1972 for natural gas and for No. 6 residual oil containing 0.5% S or less; heat rate of 9,952 Btu/Kwh computed as a weighted average for PG&E base load plants.

5/ Plant investment without water cooling derived as an average of nuclear plant costs for Sputhern California Edison and PG&E escalated at 5% from 1968-72. Fuel cost based on average cost for those plants, does not include that part of fuel cost paid by AEC as a research expense.

6/ Weighted average for base load plants except geothermal.

Source: Alvin Kaufman of Public Service Commission of New York State, Personal Communication (December 1973).

TABLE 3

ALTERNATIVE METHODS OF OIL PRODUCTION

	Year of Proven operation 1/	Lead time (years)	Investment $/bbl/day capacity	Estimated Cost at source ($bbl) equivalent 2/	Projected US-production by 1985 (mill.bbl) 3/	Present status of technology
TECHNOLOGIES						
Agro-Waste Utilization 4/	1976	3		5/	86	Pilot plant
Improved Drilling 6/	1978	5		5.0	517	Early development
Enhanced Recovery of Oil 6/	1979	6		5.0	430	Various stages
Oil Shale - Surface Processing	1979	6	5000	5.0	258	Pilot plant
Improved Auto to Reduce Fuel Consumption	1979	6			(1034) 11/	Various stages
Heavy Oil and Tar Recovery	1980	7	4000 7/	5.0	344	Early development
Methyl Fuel from Coal-Surface 8/	1981	8		10.3	258	Concept
Methyl Fuel from Coal-in situ	1982	9	6000-8000 9/	8.1	258	Concept
Coal Liquefaction	1982	9		8.6 10/	154	Small pilot plant
Oil Shale - in situ/Mining	1983	10		5.0	258	Pilot scale
Oil Shale - in situ/Nuclear	1983	10		5.3	258	Concept

Sources: Oil and Gas Journal, 17 September 1973.
Geothermal Energy, January 1974.
US Energy Outlook (National Petroleum Council).

1/ Proven operation is assumed to be approximately one year after completion of plant construction.

2/ Upper range of price as estimated in the sources.

3/ Refers to additional supplies of energy above those from current methods, in terms of equivalent thermal input, and to savings (in parentheses) of energy due to increased conversion efficiencies.

4/ No credit is included for waste disposal.

5/ Cost is set by competing technology.

6/ These entries refer to additional fuel quantities which would result from Research and Development funded by the Government.

7/ Investment costs to produce synthetic crude from Athabasca tar sands through in situ or mining methods, exclusive of infrastructure facilities. Operating costs will vary widely (National Petroleum Council, US Energy Outlook, Vol. II, Interior report, p. 142).

8/ Price of methyl fuel is assumed to be 10¢/10^6 BTU less than hi BTU gas.

9/ Source as in 7/

10/ US Eastern coal at $8.10-11/ton = 32-44¢/$10^6$ BTU.

11/ Energy savings.