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CARIBBEAN ENVIRONMENT PROGRAMME
ACTION PLAN

Overview on Energy and Environment in the Caribbean Area

prepared with the co-operation of
the United Nations Industrial Development Organization

UNEP/CEPAL
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OVERVIEW ON ENERGY AND ENVIRONMENT IN THE CARIBBEAN AREA

Prepared for the UNEP/ECLA
Caribbean Environment Project

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Note: Throughout the text the abbreviation t.c.e. refers to tons of coal equivalent.

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INTRODUCTION

This overview on energy and environment in the Caribbean area is presented as a preparatory contribution to the formulation of a strategy suited to the problems facing the countries of the region in the energy and environment sectors.

The report has been so organized as to provide basic information on the present energy situation, the regional resources, and trends identified with respect to the future energy scenario of the region and the consequences these might have for the environment. Furthermore, conclusions have been drawn from the analysis of these factors, and recommendations have been proposed not only on a general basis, but also in respect of specific steps that could be taken in the near future. However, these steps recommended will undoubtedly be re-appraised once a more direct overview has been obtained in the subsequent phases of this project.

The wider Caribbean has been taken to include 34 countries grouped in six subregions. This regional sub-division has been based mainly on geographical factors, but also on an historical perspective and possible patterns of future development. The subregions are:

Subregion 1 - Caribbean Islands
Subregion 2 - Venezuela
Subregion 3 - Colombia
Subregion 4 - Central America and Panama
Subregion 5 - Mexico
Subregion 6 - U. S. Gulf Coast.

The wider Caribbean as presented in this report is a geographical entity comprising countries with different basic energy situations and levels of development. It is well known that the energy resources are unevenly distributed throughout the region and, consequently, the countries' prospects vary. An analysis has thus been conducted for each subregion, and the findings are presented in the second part of the report.

Furthermore this report sets out to identify common problems and, where possible, to propose common strategies in order to overcome these problems, in total or in part. These are covered in the first part of this report, whereby problems have been analysed at three levels and appropriate remedial steps put forward.

Unless otherwise stated, the statistical data given in the tables have been derived from official United Nations sources. The major exception is the data presented in the tables relating to subregion 6 (U. S. Gulf Coast) for which United Nations data are not available. Unless otherwise specified, the data on energy production and consumption have always been presented in metric tons of coal equivalent (t.c.e.). The conversion of other energy sources into t.c.e. has been made using the conversion factors applied in United Nations official statistics with the exception of data relating to:

- The production and consumption of electricity from hydroelectric, geothermal and nuclear plants (but only in tables where directly specified), and
- The production and consumption of fuelwood. In the latter case, the conversion factor adopted was: 1 cubic meter of fuelwood = 0.428 t.c.e.

The production and consumption of electricity from hydroelectric, geothermal and nuclear plants have been reported in the energy production and consumption tables as divided by the average thermodynamic efficiency of the thermal power plants operating in the same region and over the same time period. If no official data were available, efficiency has been arbitrarily fixed, taking into account the country's level of industrialization. This methodology was adopted in order to provide a better understanding of the relative importance of these energy sources in the overall energy picture of the respective regions.

CONCLUSIONS AND RECOMMENDATIONS

The energy picture of the different Caribbean countries described in this report has shown a large range of situations in terms of energy resources, future energy supplies and development possibilities.

Apart from the U. S. Gulf Coast which is atypical for the Caribbean energy scenario owing to its extremely high level of present industrial development, the other countries have at least one common feature: all are developing countries, albeit at different levels, in the sense that they have still to develop most of their potentialities, above all in the energy sector. Some common approaches have been identified, mainly in respect of energy conservation and with respect to the organization of research into alternative energies. These offer a basis for common action.

However, more specific problems are of pertinence to individual countries or groups of countries. As repeatedly stated, the energy resources of the Caribbean are unevenly distributed. Since the development of each country hinges upon the availability of energy, different rates of development can already be envisaged. Stated in simple terms, it is conceivable that, independent of the present rate of development, the problems faced by countries richly endowed with energy will be different from those faced by the others. The first set of problems will be mainly related to the exploitation and management of resources, the second set will be concerned with energy supply.

It would appear difficult to establish a link between these two sets of problems. However, if the will to co-operate prevails, even only partially, in a national assessment of the problems, certain possibilities for broader co-operation can emerge:

- Horizontal co-operation between countries with the same problems and experience in particular sectors;
- Vertical co-operation between countries with the same problems, but different experiences in the same sectors.

Apart from the nature of co-operation that could be adopted, different areas of interest (always in the energy sector) on which many countries could work together have been identified and possible forms of collaboration indicated. This does not mean that national projects should not be promoted, but it is essential that the experience thus gained should be subsequently exchanged with the other countries.

Particular consideration should be given to the model of development to be adopted by all the developing countries in the area. The recent history of the developing countries throughout the world has shown the simple transfer of technologies, life-styles and development patterns from the more developed countries to developing countries with completely different background is doomed to failure for innumerable reasons, even economic ones. Consequently, the governments of the region should define a model of development appropriate to their countries, based not only on immediate economic benefits or efficiency, but also on the broader concept of socio-economic efficiency.

This means that "hard" technological innovations should be avoided in favour of "softer" technologies (such as the production of alcohol and/or methane from agricultural wastes and products, small hydropower applications, small devices for solar and wind energy utilization etc.) that ensure industrial (or agro-industrial) development in harmony with social development. Moreover, the negative impacts of these technologies on the environment should be greatly reduced.

In some cases (e.g. certain islands) this proposal is a necessity rather than a choice, since no other resources are available. Sometimes investment in this sector would seem uneconomic: however, it can be argued that, given the rapid upward trend in energy prices, what initially appears marginally uneconomic can easily become economically profitable in the short term.

In conclusion, it can be said that the use of the alternative energies cited above seems in principle most suited to the majority of countries in the Caribbean area.

ANALYSIS OF THE POSSIBLE FUTURE SOLUTIONS TO THE ENERGY PROBLEMS OF THE CARIBBEAN AREA

The wider Caribbean is a geographical entity made up of countries with different economic and political structures, national resources, social systems, potential capabilities and prospects for the future. However, as far as the energy sector and the environment are concerned, some common problems and actions can be identified at a general level independent of basic individual regional and national differences. Certain problems that can be solved at a national level can be seen to be common to other countries, and consequently a similar basic approach to their solution can be adopted. On the other hand, certain other problems can only be solved at a national level.

It is possible to define three levels of action applicable to three kinds of problems.

A) Energy and environmental problems at the regional level and possible action.

B) Energy and environmental problems at the subregional level and possible action.

C) Energy and environmental problems at the national level and possible action.

A) <u>Energy and environmental problems at the regional level and possible action</u>.

Since the wider Caribbean, at present, does not constitute a political or economic entity, any suitable joint strategy relating to the energy or environmental sectors has to be conceived in the medium or long term. This does not mean that everything has to be undertaken at some future date, as the basis for any future work has to be established now.

From the standpoint of energy supply, it seems unlikely that effective substitutes will be found for oil, gas and their derivatives in the next 20 years at least. It is also well known that energy reserves in the Caribbean are unevenly distributed: consequently, in the short term each country or group of countries will pursue a variety of energy policies, one possibly contradicting the other. However, if the energy supply problem were to be faced on a more general plane, it would be in the interests of all countries to undertake investigations into alternative forms, thus reducing dependence on oil. A common solution could touch upon these two considerations:

(a) An energy policy based on energy conservation.
This aspect has often been neglected in preference to a global solution to the energy problem based on a revolutionary, but improbable change in energy production technologies and sources. Energy conservation is a partial, but in many cases valid, alternative to energy problems. This statement holds true both for industrialized and semi-industrialized countries where the concept can be applied to the efficiency of the technological solution adopted in the industrial sector. It is equally valid for the non-industrialized countries where inefficiency can be attributed to a lack of technologies and the absence of local capability to adapt technologies.

(b) An enhancement of research into possible energy alternatives.
Many of the countries in the Caribbean region are endowed with national energy reserves which can be utilized only after an initial period of study and research. This statement is also valid for those countries which are not endowed with conventional energy reserves, but have resources that can be utilized to provide alternative forms of energy (solar, biomass, etc.). Given the national differences and degrees of potential, the only possibility for joint action in solving energy problems lies in the ability of each of the countries to define some "main area of interest" in the field of energy and environment, to which it shall address its efforts in the research and applied research sectors. Accomplishment of this goal is linked to the creation of a system for the exchange of information between the national and sub-national institutions, thereby ensuring a rapid transfer of data, technologies and experience.

The steps that could be taken in the near future to implement a common approach to energy and environmental problems in the Caribbean area are outlined below:

(i) Identification of the regional institutional capacities and human resources.
This is essential to defining the "main areas of interest" mentioned above and to appraising the capacities of the Caribbean institutions in the various research fields, whereafter common research activities can be established.

(ii) Development of an institutional network.
National and sub-national institutions should be integrated: to this end, a supra-national institution could be set up or an existing body upgraded. This institution should be initially concerned with promoting linkages and co-ordination between the institutions so as to develop joint activities.

(iii) Collection and organization of data.
Since no planning or research can be launched without input data, this should be one of the first concrete aims of the regional institutions' common work. It should be emphasized that a common methodology has to be established in order to avoid input discrepancies. One solution might be to set up a data bank collecting all the information from the different institutions, thereby paving the way for homogeneity of the incoming data as well as establishing a basic starting point for any future action.

B) <u>Energy and environmental problems at the subregional level and possible action</u>.

In the section above, the idea of main areas of interest was introduced. This would entail each country concentrating its efforts on specific energy sectors (hopefully on the environmental implications as well) in keeping with its present rate of development and potential.

The energy sectors have been identified as:

Oil and gas
Coal
Hydroelectric
Geothermal
Biomass
Solar
Other energy resources.

A brief outline of the main technologies used in these sectors and their environmental implications is given in Appendix 1.

In Table 1 the situation in respect of each of these countries is reported for each country, together with an indication of the present rate of development and potential in each sector. Even if this table has only an indicative value, it seems likely that each country will indicate its main area of interest precisely those sectors with the highest potential (i.e. those sectors with the highest numbers in each column, in Table 1).

On the other hand, it is already possible to define which countries should be able to collaborate in which sector: they will be the countries with the same area of interest, probably those with the highest potential in the same sector. Collaboration could be of two types:

- Mutual co-operation among countries already well developed in the respective sector; and
- Technical assistance among countries with different rates of development in the respective sector.

In any event, collaboration will emerge from problems that, in general, are of interest to only some of the countries or a subregional grouping, and the same could apply to any subsequent action taken. These subregional problems in the industrial energy sectors and possible remedial action are outlined below.

Oil and gas. At present oil and gas reserves are very unevenly distributed throughout the Caribbean. Since hydrocarbons will be the main source of supply in the near future as demand grows, some countries will enjoy a lower rate of development in comparison with those countries more richly endowed with oil reserves.

Certain Caribbean countries have always been known to be rich in hydrocarbons. However, recent important discoveries in certain countries and the implications these have for their future serve to underscore the importance of well organized and planned exploratory activities. The consequential evaluation of hydrocarbon reserves (even if it should prove negative) is a basic starting-point for the serious planning of future energy strategies and economic development in each country.

Table 1. Summary of the rate of development of the potential and of the energy sectors, by country

	Oil and gas	Coal	Hydroelectric	Geothermal	Biomass	Solar	Other energy resources
U.S.A. (Gulf Coast)	3 d	3 d	3 d	3 b	5 c	5 b	5 b
Bahamas	2 a	1 a	1 a	2 a	2 a	5 a	5 a
Cuba	3 c	2 a	3 b	2 a	5 b	5 a	5 a
Cayman Islands	1 a	1 a	1 a	2 a	2 a	5 a	5 a
Jamaica	2 a	2 b	3 b	2 a	5 b	5 a	5 a
Haīti	2 a	1 a	3 b	2 a	4 a	5 a	5 a
Dominican Republic	2 a	2 a	3 b	2 a	5 a	5 a	5 a
Puerto Rico	1 a	1 a	3 b	2 a	4 b	5 a	5 a
U.S. Virgin Islands	1 a	1 a	1 a	2 a	2 a	5 a	5 a
British Virgin Isl.	1 a	1 a	1 a	2 a	2 a	5 a	5 a
Antigua	1 a	1 a	1 a	2 a	2 a	5 a	5 a
St. Kitts	1 a	1 a	1 a	2 a	2 a	4 a	5 a
Montserrat	1 a	1 a	1 a	2 a	2 a	4 a	5 a
Guadeloupe	1 a	1 a	1 a	2 a	2 a	4 a	5 a
Dominica	1 a	1 a	4 c	2 a	2 a	4 a	5 a
Martinique	1 a	1 a	1 a	2 a	4 b	4 a	5 a
St. Lucia	1 a	1 a	1 a	3 a	2 a	4 a	5 a
St. Vincent	1 a	1 a	3 c	2 a	2 a	4 a	5 a
Barbados	3 b	1 a	1 a	2 a	4 b	4 a	5 a
Grenada	2 a	1 a	2 a	2 a	2 a	4 a	5 a
Netherl. Antilles	1 a	1 a	1 a	2 a	3 b	4 a	5 a
Trinidad and Tobago	5 a	1 a	1 a	2 a	3 b	4 a	5 a
Guyana	2 a	1 a	5 a	2 a	5 b	4 a	5 a
Suriname	2 a	1 a	4 c	2 a	5 b	4 a	5 a
Venezuela	5 d	2 b	5 c	2 a	4 b	4 a	5 a
Colombia	4 d	1 c	5 d	2 a	5 b	4 a	5 a
Panama	2 a	1 a	3 c	2 a	3 b	5 a	5 a
Costa Rica	2 a	1 a	5 d	4 a	5 c	5 a	5 a
Nicaragua	2 a	1 a	4 d	5 b	5 c	5 a	5 a
Honduras	2 a	2 a	4 d	2 a	5 c	5 a	5 a
El Salvador	2 a	1 a	3 d	4 d	5 c	5 a	5 a
Belize	2 a	1 a	3 a	2 a	5 c	5 a	5 a
Guatemala	3 b	1 a	5 c	5 a	5 c	5 a	5 a
Mexico	5 d	5 c	5 c	4 c	5 b	5 a	5 a

Potential

1 - very little or no potential
2 - undetermined but with some potential
3 - limited potential
4 - medium potential
5 - major potential

Rate of development

a - undeveloped
b - limited development
c - medium development
d - well developed

Should prospecting prove positive, every care should be taken to minimize losses in the system: for instance, by avoiding the flaring of gas and by utilizing special techniques so as to exploit the wells better. In any event, co-operation between interested countries should ensure a better solution to these problems. Furthermore, stringent planning of the use of hydrocarbon reserves should also prevent the rapid depletion of national reserves (as has happened or seems likely to happen in some Caribbean countries).

Special emphasis should be placed on energy conservation with respect to the use of oil and gas. Major savings of these forms of energy could be achieved by paying greater attention to the efficiency of the technologies used in different fields: for instance, by improving street lighting systems, applying better building technologies in the residential and commercial sector (primarily in the tropical regions), and promoting technological innovation in the industrial sector. On the other hand, certain sectors, such as agriculture, could greatly benefit from the partial or total replacement of oil by other, cheaper and more abundant, local resources: for example, biomass or fuelwood. This point is particularly valid for the oil-poor countries. Oil shipments in the region are particularly intense owing to the relatively high refinery capacity of the Caribbean countries and their proximity to Venezuela and the United States, a major exporter and importer of oil, respectively.

In environmental terms, the consequences are particularly negative, since it has been calculated that dumpings and losses from tankers account for one third of the total volume of hydrocarbons entering the sea /27/. Since there are legal instruments, at both the national and international level, curbing such actions, the problem calls for efficient monitoring in each country.

Given the above situation, an action programme can be developed along the following lines

(a) Promotion of co-operation between the oil-producing countries in the areas of exploration and production. Many of the national companies operating in these sectors have already proved themselves fully capable of accomplishing these tasks.

However, closer collaboration, based on a continuous exchange of experience, would increase their capability to deal with any specific problem.

(b) Promotion of co-operation between oil-producing and non oil-producing countries in respect of exploratory activities. Instead of using companies from abroad, effective use could be made of the experience acquired by the national companies in the oil-producing countries of the Caribbean. This co-operation could ensue on both a bilateral and multilateral basis.

(c) Conduct of research into energy conservation. This could be accomplished by national and sub-national research institutions co-ordinated in the manner outlined above, and the results obtained could be utilized by any country in the region.

Coal. Broadly speaking, the situation in the coal sector in the Caribbean has never been positive. Only a few countries have exploited coal to an appreciable degree. The situation changed slightly in the wake of the oil crisis and the subsequent re-evaluation of other forms of energy. Exploratory activities, primarily in the past few years, have revealed reserves in various countries. For some countries, coal could, in principle, represent an alternative solution to their energy problems.

Given this inadequate evaluation of reserves, the absence of any assessment of the infrastructure needed for coal extraction and transportation, and the lack of research into the possible utilization of the national coal reserves, major capital investment and large-scale scientific investigation will be needed before appreciable positive results can be obtained. Some of these problems could be overcome if the countries interested in developing this sector were to co-operate. Furthermore, since studies on the utilization of coal have been conducted throughout the world, co-operation with more advanced countries would also be most useful.

In terms of the impact the use of coal has on the environment, the problem must be considered very attentively. Since the combustion of coal can lead to serious pollution problems, specific strategies have to be adopted relating to the use of coal on an increasing scale. It would then seem advisable to develop a joint research programme for the efficient utilization of existing coal resources. The institutions studying these problems could also be entrusted with the task of studying: (a) the impact of the use of coal on the environment; and (b) the technologies suited to avoiding major pollution problems.

Hydroelectricity. As in the case of other energy reserves, hydrological energy reserves are concentrated on the mainland (with a few minor exceptions). In principle, hydropower is a valid alternative to thermal generation, as it is a non-polluting and renewable source of energy. However, in some cases, hydropower can also have a negative impact on the environment.

Where barrage dams are built, the tropical climate and the large mass of stagnant water are conducive to tropical diseases which can infect the population living near the man-made lake. Moreover, in a tropical environment, the possibility of silting is much greater than in a temperate climate.

For these reasons, the building of any large hydropower station should be carefully evaluated, and due account taken of any side-effects, both on the environment and on the facilities required by the plant.

Wherever possible, less ambitious projects should be promoted since large plants necessitate major capital investment and involve long construction periods. These arguments are especially valid for developing countries, where development should be accomplished by exploiting local capabilities and not by importing sophisticated technologies.

Possible actions at the subregional level for the hydropower sector are:

(a) Co-operation in the development of a common approach to the environmental impact of large-scale hydropower facilities.

(b) Development of a common approach to the specific technological problems associated with the use of large hydropower plants in humid climates.

Geothermal. Many countries in the area have shown a great interest in this sector over the past years. Some of them have started exploration and made use of geothermal wells.

Geothermal electricity production could be a good alternative form of energy, above all in countries with limited energy resources. However, prospecting normally takes a long time and, depending on the geology of the region, calls for major capital investment as well. On the other hand, the capital and management costs of the power plants are very competitive in comparison with other energy sources.

Nevertheless, some problems connected with the operation of these plants have yet to be solved. In many cases, the release into the atmosphere of heavy metals, sulphuric acid, ammonia, and other pollutants contained in the escaping gases, can give rise to serious environmental problems, if no precautions are taken. Moreover, the presence of corrosive compounds in the gases requires meticulous equipment design. However, it would be advisable to examine closely the possible geothermal resources of each country, together with studies and research devoted to their exploitation and the solution of subsequent technological and environmental problems.

Countries interested in the exploitation of their geothermal reserves could undertake certain joint activities:

(a) Promotion of a joint programme, involving both more and less advanced countries, in the geothermal sector geared to the exploitation of possible resources. Since some countries in the Caribbean region have now accumulated sufficient experience in this field, their co-operation in exploratory work with less experienced countries would be of the maximum importance. At a later stage, the same countries could also provide, in part, technical assistance to their partners in building, starting up and operating the power plants.

(b) Implementation of a joint research programme in order to study the technical problems of plant operation and the possible environmental impact of geothermal energy.

Biomass. Since the economies of many Caribbean countries are mainly based on agriculture, the possibility of utilizing agricultural products and/or residues for the production of energy is, in principle, very high. However, other studies have still to be conducted before biomass can be utilized on a large scale. Furthermore, the social impact of the use of this energy should be considered, since it involves not only the introduction of different technologies, but it also touches upon the question of local acceptance.

In any event, the exploitation of biomass could be a positive alternative for most of those countries which, for reasons of geography, history, energetics and economics, have limited prospects of being self-sufficient in terms of their energy supplies. Biomass has been used to meet some basic energy needs in the developing countries. It is hoped that this alternative form of energy will be more efficiently utilized, replacing other commercial forms of energy that are more expensive, non-renewable, and unevenly distributed.

Biomass can be utilized in different ways depending on the input and the final forms of energy produced. Three different uses are outlined below:

(a) Direct combustion.

Wood, charcoal and agricultural residues can be combusted to yield energy. Combustion is the simplest use of biomass, and it has been in use for thousands of years. Efforts are now being made to increase combustion efficiency and to organize the production of energy on a larger scale. New furnaces are being designed, as are new combustion techniques, such as fluidized beds.

On the problems that could arise with the large-scale use of direct combustion, deforestation is the first. This negative feature is already apparent in certain areas, and in the long term it should be checked, if the soil fertility is not to decrease. However, careful research coupled with serious planning should contribute to the solution of this problem. It would be advisable to proceed along the following line:

(i) Establishment of pilot plants for research and development in areas where the resource potential is known to exist. The results should be made available to all other countries interested.

(ii) Preparation of detailed socio-economic feasibility studies in selected countries (particularly those with very limited alternative sources); and

(iii) Development of research on the environmental impact and management criteria.

(b) Aerobic fermentation (production of alcohol for fuel uses). Any sugar or starch bearing crops, such as sugar cane and cassava, can be used as raw material for the production of alcohol. Despite its age, this technique has only recently been utilized for the production of energy on a larger scale. The technological problems connected with this form of production are mainly related to the end use of the alcohol. Furthermore, scaling up the plant needs further investigation. It is felt that the following steps would be beneficial:

(i) Development of research on the economic feasibility of scaling up the plants; and

(ii) Development of research on the possible use of alcohol as a fuel and on its impact on existing technological and economical structures.

(c) Anaerobic digestion (generation of biogas from vegetable and animal wastes).
This technique could be utilized to meet the energy needs of farms and small communities. The problems connected with the exploitation of these potential reserves are mainly technological and economic: collection of the raw material, disposal of sludge, distribution and use of gas, control of reactor conditions (e.g. pH, temperature, concentration), scale of operation, and capital investments. Once again these problems can be overcome through research activity, both theoretical and applied. It is felt that the following would be of benefit.

(i) Development of co-ordinated research into the problems identified above; and

(ii) Establishment of pilot plants for research and development.

Solar. The geographic location of the Caribbean region is conducive to the exploitation of solar energy. The problems are strictly technological and economic since solar technology is still underdeveloped and non-competitive. Even though it is unlikely that solar energy will replace conventional forms of energy in the near future, it can already be used on a small scale in the domestic and agricultural sector (e.g. water heating, crop drying, solar pumps). Other more sophisticated applications, such as air conditioning or the production of electricity, will emerge in the medium or long term.

In many of the Caribbean countries, most of the basic work has still to be done in order to determine the exploitable potential. This first step should be followed by applied research in the field into larger scale applications, primarily in the agricultural sector and in areas where solar energy offers major prospects of development for want of other forms of energy. It is thus suggested that the following procedure be undertaken:

(a) Meteorological data collecting, essential to the correct planning of the use of solar energy;

(b) Extended field testing of solar applications outlined above; and

(c) Analysis of the problems associated with scaling-up.

Other energy resources. Over the past few years, new problems generated by the energy crisis have urged many countries throughout the world to undertake general research into forms of energy other than oil and fossil fuels. In this connexion, studies on the possible production of energy from such sources as wind, waves, and the ocean thermal gradient have been promoted in certain Caribbean countries. As already said, it is unreasonable to expect that these new sources will replace other conventional forms of energy production in the near future. However, research in this field should be promoted in order to assess the region's potential.

For social, economic, and geographic reasons as well as energy considerations, the situation of certain Caribbean countries (e.g. the small poorly endowed islands) represents an ideal field for applied research in this sector and practical applications. This holds true for both solar and biomass energy.

In this connexion, special mention should be made of nuclear energy, since only one nuclear plant is operating in the wider Caribbean region (excluding the southern coast of the United States); it is located in the Panama Canal zone. For economic and technological reasons, this source of energy does not seem suitable for most of the developing countries in the Caribbean. However, the presence of potential uranium reserves in some areas could promote the use of nuclear energy in some of the more industrialized countries of the region.

In the light of the above, consideration might be given to the following at a subregional level:

(a) Data collecting for an evaluation of the regional energy resource potential considered above;

(b) Development of appropriate energy storage systems; and

(c) Development of applied research in the field.

At present, some projects involving different countries in specific energy problems have been implemented or are ongoing. Examples are given in Appendix 2.

C. Energy and environmental problems at the national level and possible action.

Depending on the energy policies pursued by the various countries, many development programmes have been scheduled in each sector. Apart from the main choices to be made in respect of energy policy, many countries seem interested in developing the alternative energy sector.

Further to what has already been said about co-operation at the regional and subregional level, many problems can be approached at the national level or in co-operation with international organizations, such as the United Nations. Depending on its development programme, each country can define actions at this level. In this preliminary phase, these actions need only be indicated in broad terms. Some of them have already been developed into projects for implementation by local institutions as reported in Appendix 2.

ANALYSIS OF THE ENERGY SITUATION OF THE CARIBBEAN AREA

This section of the report contains six chapters, each dealing with one of the six subregions of the wider Caribbean area presented below.

Subregion 1 - Caribbean Islands, Guyana and Suriname

Countries:
- Bahamas
- Cuba
- Cayman Islands
- Jamaica
- Haïti
- Dominican Republic
- Puerto Rico
- U. S. Virgin Islands
- British Virgin Islands
- Antigua
- St. Kitts
- Montserrat
- Guadeloupe
- Dominica
- Martinique
- St. Lucia
- St. Vincent
- Barbados
- Grenada
- Netherlands Antilles
- Trinidad and Tobago
- Guyana
- Suriname

Subregion 2 - Venezuela

Subregion 3 - Colombia

Subregion 4 - Central America and Panama

Countries:
- Guatemala
- Belize
- El Salvador
- Honduras
- Nicaragua
- Panama
- Panama (canal zone)

Subregion 5 - Mexico

Subregion 6 -- U. S. Gulf Coast

States:
- Texas
- Louisiana
- Mississipi
- Alabama
- Florida

The subregions are presented according to their geographic location read clockwise, starting with the Islands region. Within each subregion, the order of the countries or states is determined by their geographical position (from north to south and from west to east). Wherever possible, data have been reported for each country or state.

The energy situation of each subregion is presented in five sections in each chapter, each section dealing with one of the following subjects:

1. Present energy situation

   The present energy situation of the subregion is examined both globally and by country. The historical perspective is considered on the basis of recent, and less recent, data. This section is subdivided into four parts dealing with: energy production; energy trade and secondary energy production; electricity production; and energy consumption.

2. National energy resources

   Energy reserve estimates are reported globabally and, wherever possible, by country on the basis of both official and unofficial sources. Information on exploratory activities is also given.

3. National energy policies

   Trends are reported in respect of Government policies relating to the exploitation and discovery of non-renewable and renewable resources.

4. Future energy demand

   In this section, data on future energy consumption (up to year 2000) are presented as derived from different energy forecasting models and from trends extrapolated from data on energy consumed over the past few years. Furthermore, the cumulative energy demand from 1979 onwards is calculated on the basis of the energy demand figures mentioned above, the cumulative energy demand between any two years being assumed to be the sum total of the energy consumption envisaged for each year of the period under review.

5. Future national energy problems

Following a comparison of the future envisaged energy consumption with the availability of local energy resources, certain energy problems (be they the energy gap or the management and exploitation of resources) are presented.

Chapter I. Subregion 1: Caribbean Islands, Guyana and Suriname

1. Present energy situation

Production of primary energy

Except for Trinidad and Tobago, all the Caribbean countries have suffered from a lack of locally produced energy. This situation remained unchanged throughout the period under consideration (1973-76), although new discoveries have since modified the global energy production picture.

Energy production in the Caribbean Islands in the period 1973-76 is given in Table I.1. During that period, the overall increase in the production of commercial and non-commercial energy was some 17 per cent: entirely due to the growth of the commercial energy production, since the production of non-commercial energy remained approximately constant. Commercial energy production increased by 20 per cent between 1973 and 1976, with an annual growth rate of 6.3 per cent. However, this growth was unevenly distributed, being 7.2 per cent in the first year, 12.2 per cent in the second, and only 0.02 per cent in the third. From Table I.1., it can be seen that the growth in production was almost entirely due to the oil-extraction sector which expanded by 34 per cent between 1973 and 1977 (annual growth rate: 7.6 per cent).

Oil production represented some 83 per cent of the average commercial energy production in the region, and it is the main energy resource of the whole area. However, this feature is valid only for the particular case of Trinidad and Tobago where almost the entire oil production of the subregion is concentrated. The breakdown by country of the energy production for the years 1973 and 1976 is reported in Tables I.2. and I.3., respectively. From these data it can be deduced that 98.5 per cent of the oil produced in this subregion came from Trinidad and Tobago. The largest part of the Trinidad oil production comes from offshore drilling. This share increased continuously between 1973 and 1976, from 64 to 78 per cent of the total production. The drilling activities have been carried out in the shallow waters of the Gulf of Paria, located on the Continental Shelf on which both Trinidad and Tobago are placed. The remaining oil production of this subregion is shared between only two countries: Barbados and Cuba. The former has appreciably increased its production over the past years: in three years (1973-1976) production increased by more than a factor 9, reaching the rate of 150,000 barrels per year in 1976. This quantity is of some relevance to the national energy balance, but it is almost negligible set against the Caribbean energy production scenario, since it is less than 0.2 per cent of the Trinidad and Tobago oil production. Cuban oil production is seven times larger than that of Barbados, but it still represents only 1.3 per cent of the total Caribbean production. Except for these three countries, no other country produces any oil in this subregion.

In terms of gas production, the situation does not differ appreciably from that already described for oil. Since most of the gas extracted was associated with oil, only Trinidad and Tobago, Cuba and Barbados were gas producers over the period considered (1973-76). However, despite the increase in oil production, gas production remained approximately constant (only a slight decrease of six per cent between 1973 and 1977). The reason for this difference lies in the different ways in which gas can be transported compared with oil. As can be seen in Tables I.15, I.16. and I.17. gas was utilized only by producers for local use. Surplus production was normally re-injected into the oil wells (in order to increase well-productivity) or flared in large quantities (some 25 per cent of the total). In any event, gas production did not exceed 13 per cent of the subregion's production of commercial energy.

None of the countries considered produces coal. Hydroelectricity is more widely spread among the islands, and in some instances it is the only energy resource. However, only eight countries of the 23 considered exploited hydropower. Most of the time, hydroelectric energy had no significant impact upon the energy economy of the Caribbean Islands. Only in particular cases, such as Haïti, Suriname, Dominica and St. Vincent, did hydroelectricity account for a large share of the commercial energy consumed in the country (Haïti is a special case owing to the very limited consumption of commercial energy in comparison with non-commercial energy). In terms of production, Suriname produced the largest share of hydroelectricity in the subregion (57 per cent).

Nuclear and geothermal electricity are not utilized in the Caribbean Islands. Cuba is the only country which seemed seriously interested in pursuing a nuclear programme, since a basic training programme for nuclear plant operators was scheduled. On the other hand, the use of non-commercial energy resources is very widespread in the subregion; it is prevalent in countries with weak economies and, this applies to almost all the Caribbean Islands which have no other energy resources to exploit.

In the case of Cuba, fuelwood production was 2.5 times higher than that of commercial energy. However, the large imports of hydrocarbons for domestic consumption diminished the importance of non-commercial energy in the national energy scenario. The contrary is the case in Haïti and, to a certain extent, in the Dominican Republic. For these countries, the production of fuelwood was much higher than the production of commercial energy (in 1976 by a factor of 20 and 9 respectively) and, at the same time, fuelwood accounted for a large share of the domestic energy demand (90 and 18 per cent of domestic consumption of energy). In other countries, such as Guyana, Guadeloupe, and Martinique, fuelwood represented the only source of domestic energy production.

<u>Trade in energy and production of secondary energy</u>

Since none of the countries in the subregion, except for Trinidad and Tobago, could rely on sufficient national energy resources, their energy supply was mainly based on trade. In many cases, these countries depended 100 per cent on the external supply of energy. This situation was common to the little islands. In Table I.4., the overall energy trade for the period 1973-76 is reported.

The corresponding breakdown for the years 1973 and 1976 is given in Tables I.5. and I.6., respectively, whence it can be seen that Trinidad and Tobago was the only country with a positive energy balance over that period. However, its exports of hydrocarbon did not balance out the amount of oil imported into the subregion. Consequently the overall energy trade was negative throughout the period 1973-1976, with some fluctuations. Energy imports were made up almost entirely of hydrocarbons (99.93 per cent out of the total), both as crude oil (90 per cent) and as energy petroleum products (9.9 per cent). The prevalence in the imports of crude oil in comparison to oil derivatives shows that this subregion has a high refinery capacity: pertinent data are reported in Table I.7. In three years (1973-76) refinery capacity increased by some seven per cent. This capacity largely exceeded the needs of the countries, but it was a determinant for their economies, since most of the refined products were exported. In 1976, some 70 per cent of the energy imported as crude oil was re-exported in the form of refined petroleum products. However, the refineries were unevenly distributed among the islands: as a consequence, the share of energy imported as crude oil or as oil derivatives varied from country to country. On this basis it is possible to divide the countries as follows:

- Countries with a refinery capacity in excess of their needs: Bahamas, Puerto Rico, U. S. Virgin Islands, Martinique, Netherlands Antilles, and Trinidad and Tobago. The bulk of these countries' energy imports is made up of crude petroleum, and for some trade in energy is the basis of their economies. Countries such as U. S. Virgin Islands, Netherlands Antilles, Bahamas and Martinique exported a large share of their oil imports as refined products (in 1976, 87, 81, 77 and 52 per cent respectively). In Puerto Rico, refinery capacity was more oriented towards satisfying domestic demand for refined products, since only 26 per cent of the imported oil was devolved to the foreign market. For Trinidad and Tobago, the situation was slightly different because the country processed not only imported oil, but also some of its own crude petroleum production. Except for Martinique, the refinery capacity of the above countries was high: they accounted for some 93 per cent of the region's total refinery capacity. These islands created a "refinery belt" surrounding Venezuela which supplied part of the oil processed in this subregion.

- Countries with a refinery capacity lower than their needs: Barbados, Jamaica, the Dominican Republic, Cuba and Antigua. In 1976, Barbados, Jamaica, the Dominican Republic and Cuba imported 55, 51, 47 and 30 per cent, respectively, of their energy petroleum products. In the past few years, Cuba has decreased the share of imported petroleum derivatives, and increased its refinery capacity (11 per cent between 1973 and 1976). As for the energy imports of Antigua, its refinery (900,000 tons oil/year of capacity) went out of production in 1975. As a consequence, Antigua started importing only energy petroleum products.

- Countries with no refinery capacity: all the small islands of this subregion, plus Haïti, Guyana, and Suriname.

In respect of the islands, building a refinery to process crude oil for local use would not be a useful investment, whereas in larger countries with an established oil consumption, such as Suriname or Guyana, it would be convenient to start refining products for the domestic market. As for coal, only four countries (Bahamas, Cuba, Jamaica and the Dominican Republic) were importers during the period considered. Bahamas stopped imports in 1976, while Cuba consumed 98.3 per cent of the coal traded in the region.

Production of electricity

In this subregion, the production and consumption of electricity (losses included in the latter) are equal. Owing to the natural obstacle of the sea, trade in electric energy is obviously impossible.

The data reported in Table I.8. on per capita electricity consumption and the corresponding figures for installed capacity show that electric energy was not largely utilized in this subregion. The average per capita consumption was quoted at 1256 kWh/year (1976 datum). By way of comparison, the corresponding world figure was 1720. A more detailed analysis shows that the average figure for this subregion is raised appreciably by the contribution of Puerto Rico and the U. S. Virgin Islands. Were these islands to be excluded from the input data, the average per capita consumption of electricity would drop to 723 kWh/year, i.e. 57 per cent of the previous figure. Islands, such as Haïti, St. Vincent, Dominica, Grenada, St. Kitts, and St. Lucia, have extremely low figures.

The situation is even more serious owing to the lack of natural alternative resources (e.g. hydropower) that supply a large share of electricity production in other countries of Central and Latin America. In Tables I.9., I.10. and I.11., the production of electricity is reported by type with a breakdown by country for the years 1973 and 1976. The increase in electricity production between 1973 and 1976 was some 21 per cent, with an annual growth rate of 6.8 per cent. The increase was much higher for countries such as Cayman Islands (68 per cent), Haïti (48 per cent), Guadeloupe (35 per cent) and Puerto Rico (32 per cent). The increase in production in Puerto Rico was particularly relevant since, in 1973, it generated some 43 per cent of the whole area's production. In 1976, this figure rose to 47 per cent, and this increase can be almost entirely attributed to a corresponding increase in the thermal generation of electricity. This method of producing electric energy is common not only to Puerto Rico, but also to most of the other Caribbean countries.

Data in Tables I.9., I.10. and I.11. show that the bulk of the subregion's electric energy was produced by means of thermal generation (94 per cent), the remainder of hydropower. As for the islands, the production was even more pronounced in favour of thermal generation (97 per cent of the total), since a large share of the hydroelectricity produced in the subregion came from only one country, Suriname, which in 1976 produced 60 per cent of the overall hydroelectricity. Of the 23 countries considered, only eight used hydropower to meet part of their electricity requirements. On the mainland, Suriname used hydropower to produce 88 per cent of its total electricity (1976). The situation was also favourable in Dominica and St. Vincent which in 1976 produced 86 and 59 per cent, respectively, of their overall electricity production through hydropower. In 1976 Haïti produced 76 per cent of its electricity using hydropower plants (however, its global production was always very small). The other countries generating hydroelectricity were only relatively large islands (Cuba, Jamaica, Dominican Republic, Puerto Rico), but the proportion of overall production covered by these means was very small (between two and seven per cent).

In terms of installed power plant capacity, Table I.12. gives the total capacity for the period 1973-76, while Table I.13. and I.14. present the corresponding breakdown by country for the years 1973 and 1976. The total growth of the sector was some 25 per cent. Since this figure is higher than the corresponding increase in electricity generated, it can be deduced that the plant utilization factor decreased over the period considered. Closer examination reveals that this is true for the thermal generation sector (which dominated production), but not true for hydropower stations. As a consequence of the increase in oil prices, the general trend was to utilize to a greater degree the the scarce yet renewable hydroelectric resources of the region instead of oil. The overall efficiency of the thermal power plants operating in this area was assumed to be 26 per cent (i.e. 3300 Kcal/kWh produced).

No nuclear or geothermal power plants are in operation in the Caribbean Islands.

Consumption of energy

The overall consumption of energy in this subregion for the period 1973-76 and the breakdown for 1973 and 1976 are reported in Tables I.15., I.16. and I.17., respectively. From Table I.15.,it can be seen that energy consumption decreased by 2.3 per cent between 1973 and 1976. This decrease was even higher in the period 1973-75 when the consumption of energy dropped by 5.8 per cent in only two years. This fact can be attributed solely to a decrease in the consumption of hydrocarbons (2.5 per cent for oil and 6 per cent for gas). On the other hand, the consumption of coal and hydroelectricity increased: the former by 4.3 per cent (despite large fluctuations), and the latter by 25 per cent. However, since hydrocarbons (and oil in particular) dominated the market, their influence in the energy consumption sector was appreciably higher than that of the other energy sources.

In order to understand the reason for the large drop in the consumption of energy between 1973 and 1975, it should be recalled that in some of the countries in the subregion a large proportion of the energy was utilized to process imported crude oil. These countries, such as the Netherlands Antilles, Bahamas, Trinidad and Tobago, U.S. Virgin Islands, and Puerto Rico had a large refinery capacity (see Table I.7.).

The refinery capacity of these countries was partially utilized to process Venezuelan oil. In particular, in 1973, countries such as the Netherlands Antilles and Puerto Rico imported 69 and 55 per cent, respectively, of their total crude oil imports from Venezuela. Other countries (Bahamas, Trinidad and Tobago, U. S. Virgin Islands) diversified their primary sources of oil and imported from many different countries. When between 1973 and 1975 Venezuela decreased its oil exports by more than 30 per cent, the first group of countries suffered from a lack of primary oil to process but, at the same time, they expended less energy processing crude oil. In this case, the drop in the energy consumption can be attributed mainly to the Netherlands Antilles and Puerto Rico. However, the oil crisis at the beginning of the '70s and the subsequent rise in oil prices produced a general decrease in the consumption of energy in many countries or, at least, slowed down the rate at which energy consumption grew. After 1975 the energy consumption increased again: between 1975 and 1976, the rate of growth was 3.7 per cent, 83 per cent of which was induced by a new increase in the consumption of oil.

As for natural gas, its consumption was limited to the producing countries: 99 per cent was concentrated in Trinidad and Tobago. Between 1973 and 1976, the slight drop in its consumption (6 per cent) can be attributed to the reasons quoted above. The use of coal was extremely limited, and the fluctuations in consumption were not very significant in respect to the global energy consumption scenario.

In respect of hydroelectricity, the same can be said of consumption as of production, since trade in electricity was not feasible among the islands.

As for the use of energy, the industrial sector utilized the largest share, followed by the residential and commercial sector. A breakdown of energy use in selected countries is given below, shown as a percentage of the overall national energy consumption [1]:

	Industrial	Residential and commercial	Others (incl. agriculture)	Losses
Jamaica	48.5	32.4	8.5	10.6
Haiti	42.9	19.1	13.0	25.0
Dominican Rep.	26.1	36.9	7.6	29.4
Trinidad + Tobago	56.6	30.2	0.8	12.4
Guyana	70.8	14.6	1.6	13.0

2. National energy resources

Of all the subregions examined in this report, the Caribbean area is the least endowed with natural energy resources. Even the few available resources are unevenly distributed among the countries. The unfavourable energy situation applicable to most of the islands was already underscored in the previous paragraph. Prospects for the future would not appear much better. Hydrocarbon deposits, both as oil and natural gas, are mainly concentrated in Trinidad and Tobago. The hydrocarbon reserves enjoyed by the other countries are insufficient to meet future energy requirements. Whereas new oil or gas deposits can always be discovered, not too many hopes should be placed therein, given the present results of explorations.

Coal reserves are also modest. Furthermore this energy source does not, in principle, appear very attractive owing to transportation and pollution problems. Even hydroelectric reserves are scarce and mainly concentrated on the mainland (Suriname and Guyana). Natural features of most of the countries (i.e. small islands) preclude the existence of major rivers and consequently limit the possibility of finding hydroelectric reserves.

As for deposits of geothermal and nuclear fuels, explorations are only in the initial stages: however, it seems unlikely that a highly sophisticated technology such as nuclear energy could be successfully applied in this area. Moreover, the dependency on external countries would be still more increased in the wake of know-how and fuel imports.

The countries in this subregion seem to be confronted with an unending shortage of energy, unless the use of alternative energy sources, such as solar, wind, and agricultural waste, can offer them independence, or at least, less dependence, on external sources of energy. Certain conditions, such as the lack of local resources, geographical position, developing economy, and an abundance of alternative energies conducive to industrial applications, would seem to pave the way for possible developments in this new direction.

The energy reserves of the subregion are examined in greater detail below.

Petroleum reserves

The known petroleum reserves of the subregion are concentrated in a few countries, the current oil-producers. Trinidad and Tobago, the main oil-producer of the region, also has the largest oil reserves, estimated at 1 billion barrels. At the 1976 rate of extraction, oil reserves should be exhausted before 1990, unless other oil discoveries are made.

The oil reserves of Barbados are some 1,000 times smaller. In order to understand the impact of these reserves on the national energy strategy, it should be recalled that, at the 1976 rate of extraction, these reserves will last only seven years. Moreover, in 1976 the national oil production satisfied only 12 per cent of the domestic energy consumption. Consequently, Barbados' prospects of achieving independence in terms of oil do not seem very positive. Official data relating to the oil reserves of Cuba, the other oil producer in the subregion, are not available.

As far as the other countries are concerned, estimates have not yet been made; several studies, however, have been commissioned. The best, even if limited, prospects are concentrated in the Dominican Republic which could have a potential of 200 million barrels. In Jamaica some traces of oil have also been discovered, and more intense explorations will be carried out between 1978 and 1982. Positive results are also expected following prospecting in Haïti, Grenada, Guyana and Suriname.

Gas reserves

The estimated gas reserves of the subregion are also concentrated in the oil-producing countries. In Trinidad and Tobago, which hitherto would seem to have the largest potential, gas reserves have been conservatively estimated at 12.04 trillion cubic feet (1978 datum). However, actual reserves may well be much higher, of the order of some 21 trillion cubic feet. By way of comparison, the 1976 production was 18.5 billion cubic feet. These reserves should guarantee Trinidad and Tobago a long-term energy supply even if the national oil reserves should run out. Barbadian gas reserves are much less: a conservative figure indicates some 933 million cubic feet. Data as to Cuban reserves are not available. As in the case of oil, other Caribbean countries are expected to have gas reserves: however, no specific evaluations have been made. Countries, such as the Dominican Republic and Suriname, which are expected to have oil reserves, should also have the best prospects in respect of natural gas.

Coal reserves

In comparison with oil, coal is of almost negligible importance in the energy scenario of the subregion. Whereas exploratory activities in respect of oil have been limited, those in respect of coal have been still more so. Thus far, none of the countries in the subregion have been shown to have coal deposits, except for Jamaica. However, even in this case, coal quality is poor (peat) and there are no available data about the industrial exploitation thereof started in 1977.

Hydroelectric reserves

Generally speaking, the prospects for the exploitation of hydropower are not very favourable in this subregion. The reason for this lies in the natural characteristics of the countries, which are often small islands with small rivers and sometimes no rivers at all. Consequently the use of hydropower has always been very limited. The best prospects in this sector are confined to the largest islands or to countries on the mainland, such as Guyana or Suriname, which have rivers of some magnitude.

Guyana, which at present has no hydropower stations, has the largest hydroelectric potential estimated at some 7,000 MW spread over 15 different sites. Hitherto, the high capital investment required by the hydropower stations has prevented the exploitation of these reserves. A 1,000 MW power plant was scheduled to be built on the Mazaruni river, but the lack of capital caused work to be suspended.

Suriname, which at present has the largest hydropower stations in the Caribbean, also has a project for the construction of a 1,000 MW plant. Cuba, which in 1976 generated less than one per cent of its global electricity production by hydropower, has a potential of some 1,000 MW. However, this figure also includes resources that cannot be economically exploited. The potential reserves of the Dominican Republic would seem to be in the same order of magnitude. Haïti and Jamaica have a possible hydroelectric potential of 600 and 400 MW, respectively, of which only one fifth is economically exploitable. On comparing these figures with present electric energy consumption, it can be deduced that the prospects of ensuring large shares of the electricity production through hydropower are not very positive.

Of the small islands, only Dominica and St. Vincent exploited hydropower to an appreciable degree and prospects in this sector are positive. Grenada is also assumed to have some reserves; however, studies of its potential have yet to be completed.

As for the other islands, the situation is negative, marked by a lack of studies, a lack of natural resources and, sometimes, un-economic exploitation of the scarce potential. The continuing rise in oil prices could only change this picture marginally.

Geothermal reserves

Not many efforts have been dedicated to the evaluation of the geothermal resources in this subregion. The most accurate exploratory activity to date was carried out in St. Lucia, and the results have indicated potential exploitable reserves, suitable for the production of some 10 MW. Other explorations were carried out in Dominica, Montserrat, Grenada, Haïti and Jamaica. The results for the first two countries are not available.

In 1977 a commission, entrusted with the task of studying the geothermal problem, visited Haïti and Jamaica. However, since the studies are only at the very initial stage, no conclusions can be drawn. Drilling which should follow the first phase will offer a better indication of the prospects for the future utilization of geothermal energy.

Uranium reserves

The only two countries in the region to have undertaken attempts to discover radioactive material have been Jamaica and Guyana. During the 50's research was carried out in Jamaica, but failed to reveal any significant uranium deposits. Better results were obtained in Guyana, but no data are available. Further exploration was scheduled in order to determine the extent of the reserves.

Except for Cuba, the other countries do not seem particularly interested in developing the nuclear sector, with consequent negligible exploratory activity. Cuba is more interested in a nuclear programme, and a nuclear plant was scheduled to be built in the near future. However, no data are available as to the country's uranium reserves.

Non-commercial energy reserves

The only forms of energy available in all the countries of the subregion are those derived from the sun and from by-products of the main local resource: agriculture.

Even if many studies have yet to be completed, the subregion offers major potential for the use of solar energy. Solar radiation in the region is reported to average 5 kWh/m^2 day [2], considered on an annual basis. In the near future, solar energy could be put to practical application, mainly in the agricultural sector, such as crop drying, water distillation, and water pumps.

As for the production of energy from agricultural waste, the subregion offers a very high potential. Two of the main agricultural products of the region are sugar cane and rice. According to Ref. [2] the potential production of energy obtained by burning waste (bagasse and respectively husks) in the countries reported below is of the order of some 7.38 million t.c.e. (by way of comparison, the corresponding electric energy production in 1976 was 13.618 billion kWh equivalent to 6.442 million t.c.e., taking efficiency into account). It is assumed that the energy content of bagasse (dry) is 4,400 Kcal/kg bagasse (dry), and that of husks 3,000 Kcal/kg.

The breakdown of agricultural production and potential energy production is given below [2].

Country	Estimated bagasse yield (thousands of metric tons)	Corresponding potential energy production (million t.c.e.)	Estimated husk production (thousands of metric tons)	Corresponding potential energy production (thousand t.c.e.)
Cuba	7,800	4.90	112.75	48.32
Jamaica	544	0.34	0.50	0.21
Haïti	417	0.26	32.75	14.03
Dominican Republic	1,640	1.03	71.50	30.64
St. Kitts	48	0.03	N.A.	N.A.
Barbados	138	0.08	N.A.	N.A.
Trinidad and Tobago	348	0.22	5.00	2.14
Guyana	615	0.39	43.22	18.52
Suriname	N.A.		43.12	18.48

These projections indicate most promising results in principle. Sugar cane as well as starch and sugar-rich agricultural products, in general, can be used to produce alcohol for fuel purpose. Rum is mostly produced by means of fermentation, and surplus sugar cane could be used to yield alcohol. By way of example [3] in 1976, Jamaica produced 122,000 long tons of molasses (derived from sugar cane processing). 58 per cent was used for domestic purposes (mainly for rum production), and the remainder was exported. The alcohol that could have been produced from the molasses exported was of the order of 18,000 cubic metres or 22,000 t.c.e.

Whereas the prospects of the subregion in this sector are positive, the subregional energy resource potential to be obtained from the anaerobic fermentation of animal and agricultural waste is more difficult to evaluate. However, estimates [2] do offer some ground for optimism.

3. National energy policies

Over the past 30 years the energy situation of the subregion has undergone a radical change in terms of both production and consumption. This evolution can be summarized as follows:

- Increase in energy consumption. Appreciable growth was registered in all countries as an almost totally agricultural economy developed into one based on industrialization, although agriculture still remains the basis of some national economies.

- Change in the energy sources used. Originally most of the energy consumed was derived from non-commercial energy sources (e.g. agricultural waste) or from the small-scale application of hydropower or other forms of commercial energy. After 30 years, the energy market is now almost entirely covered by oil, the only exception being certain countries such as Haïti with weak economies and very limited energy consumption.

The first point is common to many developing countries and can be considered an obligatory step in any development (even though some side-effects arising out of the forced industrialization of agriculturally-oriented areas could "boomerang").

The second point is more susceptible to change and improvement. In this case, as in many other developing countries, the lack of an adequate energy programme suited to the country has invoked a situation that the Government of each single country is now obliged to face: on the one hand, the need for oil in order to carry out development programmes and the diminished purchasing power as a result of increased oil prices, on the other. The countries in the subregion have never pursued an autonomous energy policy. This is reflected in the choices they made in the past when new technologies and energy sources were utilized without due consideration being paid to national capabilities and resources. Guyana is a good example: its hydroelectric potential is the highest of the region, yet the country is totally dependent on oil imports. At present, 38.4 per cent of the electricity is produced in thermal power plants.

In Trinidad and Tobago, the only country which has an overproduction of energy, energy policies were more devoted to solving short-term problems, rather than taking into account the possible long-term consequences. Despite the short service-life of the oil wells (by mid-1980's the present reserves should be exhausted unless new discoveries are made) oil production in 1977 was nine per cent higher than the previous year. At the same time, some 25 per cent of the gas extracted together with oil was flared or vented off. Only in the past few years have some measures been launched in order to change this trend. For example, wells producing too much gas associated with oil should be closed down on a temporary basis pending an improvement in technology so as to utilize this resource more effectively. As for the other countries in the subregion, the oil-price increases have already limited the countries' future development.

On the other hand, the oil-price increases have obliged each country to face their energy problems more realistically and to try to find alternative and autonomous solutions, wherever possible. Most of the governments have started re-investigating the possibility of locating conventional sources of energy in their countries. They have promoted prospecting, which in some cases has yielded good results (Barbados, Dominica, St. Vincent and St. Lucia). In all those cases where this solution could not be adopted, future strategies should aim at reducing their oil imports and avoiding losses of energy, and they should also investigate the possible application of alternative energy sources in connexion with the local economy and resources (e.g. agriculture), in order to meet their energy needs.

4. Future energy demand

Estimation as to the future consumption of energy in this subregion are rather uncertain because of the many factors that could affect the subregion's development. Ref. [4] reports the average annual growth rates for different periods considered:

Country	1950-1975	1950-1960	1960-1970	1970-1975	1975-1976
Bahamas	17.2	22.1	13.4	15.2	4.2
Cuba	7.1	8.9	4.2	4.1	4.0
Dominican Republic	13.0	11.9	12.1	8.5	0.2
Jamaica	14.7	18.2	13.3	10.5	0.3
Trinidad and Tobago	5.7	7.2	9.6	- 4.6	10.5
Netherlands Antilles	- 1.1	- 1.3	2.9	- 8.9	11.5
TOTAL CARIBBEAN	4.4	3.8	6.5	1.3	4.7

Considering the total growth rate over the period 1950-75 (4.4 per cent) and assuming this as a constant growth rate for the future, energy consumption can be deduced for the years 1985 and 2000 at 71 and 136 million t.c.e., respectively. These figures should not be too far from the reality since they are derived from an average of the growth rates of countries with completely different economies. An extrapolation for each country would be less significant: some of the countries in the subregion enjoyed a very high average growth-rate between 1950 and 1975 (e.g. the Dominican Republic, 13 per cent) owing to the fact that, at the beginning of the 50's, their energy consumption was extremely low and increased rapidly with the introduction of new technologies. By way of comparison, another reference [5] quotes the future energy growth rate of Dominican Republic as 6.8 per cent. The cumulative demand for commercial energy from 1979 onwards was deduced by assuming a growth rate of 4.4 per cent. Up to 1985 this demand should be some 404 million t.c.e., and up to year 2000 the corresponding figure should be 2032 million t.c.e.

5. Future national energy problems

Of all the subregions in the wider Caribbean, this region will be the one to feel most dramatically the impact of the energy crisis on its rate of development. In the previous section the cumulative energy demand of the subregion between 1979 and the year 2000 was evaluated at some 2000 million t.c.e.

By comparing this figure with the present and even potential resources of the countries in the subregion, it can be deduced that the subregion will not be able to achieve self-sufficiency in energy. (This statement does not hold true for Trinidad and Tobago whose problems seem more similar to those of Venezuela.) On the contrary, unless some well-evaluated (and possibly joint) energy policy is undertaken in time, the subregion seems bound to become completely dependent on foreign imports, with all the consequences this has on socio-economic development.

Even taking into account the fact that the subregion will of necessity be obliged to import energy (mainly in the form of hydrocarbons) to meet some basic needs, this dependency can, for most of these countries, only be reduced by developing alternative energies, possibly linked with existing economic activities (mainly agriculture).

Apart from the use of particularly sophisticated (and also expensive) alternative solutions (e.g. conversion of solar into electrical energy), the subregion seems well-suited to the first large-scale application of many non-conventional methods for the production of energy (e.g. solar crop drying, solar desalinization, solar water pumps, biomass conversion through direct combustion, aerobic or anaerobic fermentation, small hydropower and geothermal power plants, small devices for wind energy utilization, etc.), coupled with a strict energy conservation policy. The negative constraints examined above might also be a valid incentive for the adoption of this policy.

Table I.1. Caribbean Islands, Guyana and Suriname: production of primary energy
(Millions of metric tons of coal equivalent)

	Total commercial energy	Liquid fuel	Gas fuel	Solid fuel	Primary 1/ hydro and geo electricity	Nuclear electricity	Fuelwood 2/	Total primary energy
1950	5.179	4.348 (4.322)	0.635 (0.633)	-	0.146	-	N.A.	N.A.
1960	10.103	8.865 (8.844)	1.023 (1.020)	-	0.215	-	N.A.	N.A.
1970	14.100	10.878 (10.644)	2.488 (2.484)	-	0.734	-	N.A.	N.A.
1973	16.374	13.159 (12.953)	2.435 (2.411)	-	0.781	-	3.061	19.435
1974	17.549	14.439 (14.181)	2.234 (2.206)	-	0.876	-	3.063	20.612
1975	19.671	16.753 (16.497)	2.038 (2.013)	-	0.880	-	3.069	22.740
1976	19.671	16.406 (16.165)	2.287 (2.254)	-	0.978	-	3.024	22.695
1977	N.A.	17.621 (17.378)	2.288 (2.254)	-	N.A.	-	N.A.	N.A.

Source: Data derived from U.N. statistics, primarily Ref. [7]

Note: The production of Trinidad and Tobago is shown in parentheses.

1/ Conversion factor: 100 kW produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Calorific value: 3×10^6 Kcal/m^3.

Table I.2. Caribbean Islands, Guyana and Suriname: production of primary energy by country (1973)

(Millions of metric tons of coal equivalent)

	Total commercial energy	Liquid fuel	Gas fuel	Solid fuel	Primary[1/] hydro and geo electricity	Nuclear electricity	Fuelwood[2/]	Total primary energy
Cuba	0.253	0.203	0.019	-	0.031	-	0.643	0.896
Jamaica	0.046	-	-	-	0.046	-	-	0.046
Haïti	0.054	-	-	-	0.054	-	1.607	1.661
Dominican Republic	0.027	-	-	-	0.027	-	0.788	0.815
Puerto Rico	0.142	-	-	-	0.142	-	-	0.142
Dominica	0.004	-	-	-	0.004	-	-	0.004
St. Vincent	0.004	-	-	-	0.004	-	-	0.004
Barbados	0.007	0.003	0.004	-	-	-	-	0.007
Trinidad and Tobago	15.364	12.953	2.411	-	-	-	0.005	15.369
Suriname	0.473	-	-	-	0.473	-	0.002	0.475
Others	-	-	-	-	-	-	0.016	0.016
TOTAL	16.374	13.159	2.434	-	0.781	-	3.061	19.435

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1 kW corresponds to 3310 Kcal (efficiency of 26 %).

2/ Calorific value: $3x10^6$ $Kcal/m^3$.

Table I.3. Caribbean Islands, Guyana and Suriname: production of primary energy by country (1976)
(Millions of metric tons of coal equivalent)

	Total commercial energy	Liquid fuel	Gas fuel	Solid fuel	Primary[1/] hydro and geo electricity	Nuclear electricity	Fuelwood[2/]	Total primary energy
Cuba	0.267	0.212	0.028	-	0.027	-	0.643	0.910
Jamaica	0.069	-	-	-	0.069	-	-	0.069
Haïti	0.077	-	-	-	0.077	-	1.607	1.684
Dominican Republic	0.085	-	-	-	0.085	-	0.744	0.829
Puerto Rico	0.150	-	-	-	0.150	-	-	0.150
Dominica	0.008	-	-	-	0.008	-	-	0.008
St. Vincent	0.004	-	-	-	0.004	-	-	0.004
Barbados	0.034	0.029	0.005	-	-	-	-	0.034
Trinidad and Tobago	18.419	16.165	2.254	-	-	-	0.004	18.423
Suriname	0.558	-	-	-	0.558	-	0.009	0.567
Others	-	-	-	-	-	-	0.017	0.017
TOTAL	19.671	16.406	2.287	-	0.978	-	3.024	22.695

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.43 t.c.e. (efficiency of 26 %).

2/ Calorific value: $3x10^6$ $Kcal/m^3$.

Table I.4. Caribbean Islands, Guyana and Suriname: energy trade
(Millions of metric tons of coal equivalent[1/])

	1973	1974	1975	1976
Crude petroleum				
Import	183.989	170.225	135.441	157.408
Export	7.653	5.290	10.854	10.572
Energy balance (Exp.-Imp.)	-176.336	-164.935	-124.587	-146.836
Energy petroleum products				
Import	21.032	20.398	42.352	17.272
Export	133.492	134.590	103.580	113.525
Energy balance (Exp.-Imp.)	+112.460	+114.192	+61.228	+96.263
Natural Gas				
Import	-	-	-	-
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-	-	-	-
Solid fuel				
Import	0.105	0.091	0.105	0.120
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-0.105	-0.091	-0.105	-0.120
TOTAL				
Import	205.126	190.714	177.898	174.790
Export	141.145	139.880	114.434	124.097
Energy balance (Exp.-Imp.)	-63.981	-50.834	-63.464	-50.693

Source: Data derived from U.N. statistics, primarily Ref. [7], except for energy petroleum products obtained as difference.

1/ 1 ton petroleum = 1.47 metric tons of coal equivalent

Table I.5. Caribbean Islands, Guyana and Suriname: energy trade by country (1973)
(Millions of metric tons of coal equivalent 1/)

	Crude petroleum			Energy petroleum products			Solid fuels			TOTAL		
	Import	Export	Energy balance (Exp.-Imp.)	Import	Export	Energy balance (Exp.-Imp.)	Import	Export	Energy balance (Exp.-Imp.)	Import	Export	Energy balance (Exp.-Imp.)
Bahamas	21.050	-	-21.050	1.395	15.275	+13.880	0.005	-	-0.005	22.450	15.275	-7.175
Cuba	7.707	-	-7.707	2.767	-	-2.767	0.098	-	-0.098	10.572	-	-10.572
Cayman Islands	-	-	-	0.031	-	-0.031	-	-	-	0.031	-	-0.031
Jamaica	2.617	0.037	2.580	1.649	0.094	-1.555	0.001	-	-0.001	4.267	0.131	-4.136
Haïti	-	-	-	0.187	-	-0.187	-	-	-	0.187	-	-0.187
Dominican Republic	1.396	-	-1.396	1.568	-	-1.568	0.001	-	-0.001	2.965	-	-2.965
Puerto Rico	24.843	-	-24.843	1.394	5.623	+4.229	-	-	-	26.237	5.623	-20.614
U. S. Virgin Islands	37.256	-	-37.256	0.279	27.685	+27.406	-	-	-	37.535	27.685	-9.850
Br. Virgin Islands	-	-	-	0.012	-	-0.012	-	-	-	0.012	-	-0.012
Antigua	0.876	-	-0.876	0.002	0.036	+0.334	-	-	-	0.878	0.336	-0.542
St. Kitts	-	-	-	0.014	-	-0.014	-	-	-	0.014	-	-0.014
Montserrat	-	-	-	0.009	-	-0.009	-	-	-	0.009	-	-0.009
Guadeloupe	-	-	-	0.205	-	-0.205	-	-	-	0.205	-	-0.205
Dominica	-	-	-	0.013	-	-0.013	-	-	-	0.013	-	-0.013
Martinique	0.714	-	-0.714	-	0.192	+0.192	-	-	-	0.714	0.192	0.522
St. Lucia	-	-	-	0.040	-	-0.040	-	-	-	0.040	-	-0.040
St. Vincent	-	-	-	0.020	-	-0.020	-	-	-	0.020	-	-0.020
Barbados	0.228	-	-0.228	0.288	0.016	-0.272	-	-	-	0.516	0.016	-0.500
Grenada	-	-	-	0.028	-	-0.028	-	-	-	0.028	-	-0.028
Netherlands Antilles	66.581	2.722	-63.859	9.196	60.970	+51.774	-	-	-	75.777	63.692	-12.085
Trinidad and Tobago	20.721	4.894	-15.827	0.044	23.301	+23.257	-	-	-	20.765	28.195	+7.430
Guyana	-	-	-	0.888	-	-0.888	-	-	-	0.888	-	-0.888
Suriname	-	-	-	1.003	-	-1.003	-	-	-	1.003	-	-1.003
TOTAL	183.989	7.653	-176.336	21.032	133.492	+112.460	0.105	-	-0.105	205.126	141.145	-63.981

Source: Data derived from U.N. statistics, primarily Ref. [[illegible]].

1/ 1 ton petroleum = 1.47 metric tons of coal equivalent.

Table I.6. Caribbean Islands, Guyana and Suriname: energy trade by country (1976)
(Millions of metric tons of coal equivalent[1/])

	Crude petroleum			Energy petroleum products			Solid fuels			Total		
	Import	Export	Energy balance (Exp.-Imp.)	Import	Export	Energy balance (Exp.-Imp.)	Import	Export	Energy balance (Exp.-Imp.)	Import	Export	Energy balance (Exp.-Imp.)
Bahamas	13.965	-	-13.965	1.353	10.710	+9.357	-	-	-	15.318	10.710	-4.608
Cuba	8.977	-	-8.977	2.771	-	-2.771	0.118	-	-0.118	11.866	-	-11.866
Cayman Islands	-	-	-	0.036	-	-0.036	-	-	-	0.036	-	-0.036
Jamaica	2.131	-	-2.131	2.185	0.048	-2.137	0.001	-	-0.001	4.317	0.048	-4.269
Haïti	-	-	-	0.194	-	-0.194	-	-	-	0.194	-	-0.194
Dominican Republic	1.970	-	-1.970	1.130	-	-1.130	0.001	-	-0.001	3.101	-	-3.101
Puerto Rico	20.874	-	-20.874	0.937	5.453	+4.516	-	-	-	21.881	5.453	-16.358
U. S. Virgin Islands	40.134	-	-40.134	0.374	34.859	+34.485	-	-	-	40.508	34.859	-5.649
Br. Virgin Islands	-	-	-	0.012	-	-0.012	-	-	-	0.012	-	-0.012
Antigua	-	-	-	0.331	-	-0.331	-	-	-	0.331	-	-0.331
St. Kitts	-	-	-	0.019	-	-0.019	-	-	-	0.019	-	-0.019
Montserrat	-	-	-	0.014	-	-0.014	-	-	-	0.014	-	-0.014
Guadeloupe	-	-	-	0.253	0.006	-0.247	-	-	-	0.253	0.006	-0.247
Dominica	-	-	-	0.014	-	-0.014	-	-	-	0.014	-	-0.014
Martinique	0.676	-	-0.676	0.002	0.350	+0.348	-	-	-	0.678	0.350	-0.328
St. Lucia	-	-	-	0.040	-	-0.040	-	-	-	0.040	-	-0.040
St. Vincent	-	-	-	0.019	-	-0.019	-	-	-	0.019	-	-0.019
Barbados	0.191	-	-0.191	0.231	0.003	-0.228	-	-	-	0.422	0.003	-0.419
Grenada	-	-	-	0.020	-	-0.020	-	-	-	0.020	-	-0.020
Netherlands Antilles	51.538	1.335	-50.203	5.424	42.056	+36.632	-	-	-	56.962	43.391	-13.571
Trinidad and Tobago	16.952	9.237	-7.715	0.137	20.040	+19.903	-	-	-	17.089	29.277	+12.188
Guyana	-	-	-	0.856	-	-0.856	-	-	-	0.856	-	-0.856
Suriname	-	-	-	0.910	-	-0.910	-	-	-	0.910	-	-0.910
TOTAL	157.408	10.572	-146.836	17.262	113.525	+96.263	0.120	-	-0.120	174.790	124.097	-50.693

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.7. Caribbean Islands, Guyana and Suriname: refinery capacity (Millions of metric tons of crude petroleum)

	1973	1974	1975	1976
Bahamas	25.000	25.000	26.100	26.750
Cuba	5.700	5.700	6.000	6.350
Jamaica	1.850	1.850	1.850	1.850
Dominican Republic	1.500	1.500	1.500	1.500
Puerto Rico	16.000	16.580	17.150	16.580
U. S. Virgin Islands	25.000	30.200	36.400	36.400
Antigua	0.900	0.900	0.900	0.900
Martinique	0.550	0.550	0.550	0.550
Barbados	0.150	0.150	0.150	0.150
Netherl. Antilles	45.000	45.000	42.450	40.100
Trinidad and Tobago	22.500	23.050	23.050	23.050
TOTAL	144.150	149.480	156.100	154.180

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.8. Caribbean Islands, Guyana and Suriname: per capita electricity consumption (kWh) and per capita installed capacity (kW) of power plants

	1973		1974		1975		1976	
	per capita consumption	per capita installed capacity	per capita consumption	per capita installed capacity	per capita consumption	per capita installed capacity	per capita consumption	pe in ca
Bahamas	3,395	1.274	3,360	1.325	3,172	1.250	2,844	
Cuba	631	0.174	655	0.179	705	0.180	761	
Cayman Islands	1,692	0.538	2,077	0.692	2,357	0.786	2,643	
Jamaica	1,109	0.334	1,137	0.340	1,141	0.336	1,156	
Haïti	32	0.017	32	0.020	34	0.019	45	
Dominican Republic	509	0.123	554	0.154	562	0.150	556	(
Puerto Rico	4,388	1.027	4,820	1.324	5,202	1.289	5,336	
U. S. Virgin Islands	8,598	2.915	8,276	2.747	7,912	2.626	7,579	:
Br. Virgin Islands	1,300	0.400	1,200	0.400	1,200	0.400	1,000	(
Antigua	559	0.265	594	0.290	629	0.300	662	(
St. Kitts	338	0.200	338	0.200	348	0.197	348	(
Montserrat	667	0.333	667	0.333	692	0.308	692	(
Guadeloupe	409	0.117	458	0.115	480	0.127	528	(
Dominica	178	0.68	176	0.68	187	0.80	197	(
Martinique	469	0.134	475	0.137	501	0.143	526	C
St. Lucia	343	0.120	364	0.127	357	0.125	409	C
St. Vincent	172	0.061	170	0.060	170	0.090	170	C
Barbados	872	0.276	849	0.280	881	0.276	923	C
Grenada	263	0.074	260	0.073	238	0.067	292	C
Netherl. Antilles	6,624	1.239	6,723	1.218	5,785	1.198	6,639	1
Trinidad and Tobago	1,144	0.316	1,130	0.379	1,116	0.373	1,254	C
Guyana	476	0.224	478	0.220	484	0.215	508	C
Suriname	3,810	0.751	3,864	0.732	2,846	0.713	3,069	C
TOTAL	1,112	0.285	1,174	0.327	1,209	0.320	1,256	C

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.9. Caribbean Islands, Guyana and Suriname: production of electricity by type
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	2.998	2.688	0.310	-	1.315	1.315	-	1.683	1.373	0.310
1960	7.765	7.310	0.455	-	2.244	2.244	-	5.521	5.066	0.455
1970	21.272	19.736	1.536	-	4.957	3.957	1.000	16.315	15.779	0.536
1973	29.942	28.295	1.647	-	6.523	5.541	0.997	23.404	22.754	0.650
1974	32.446	30.597	1.849	-	6.658	5.652	1.006	26.515	25.672	0.843
1975	34.254	32.391	1.863	-	6.023	5.001	1.020	28.231	27.388	0.843
1976	36.490	34.439	2.051	-	6.432	5.256	1.176	30.058	29.183	0.875

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.10. Caribbean Islands, Guyana and Suriname: production of electricity by type
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
Bahamas	0.645	0.645	-	-	-	-	-	0.645	0.645	-
Cuba	5.703	5.641	0.062	-	1.120	1.120	-	4.583	4.521	0.062
Cayman Islands	0.022	0.022	-	-	-	-	-	0.022	0.022	-
Jamaica	2.187	2.088	0.099	-	0.935	0.935	-	1.252	1.153	0.099
Haïti	0.141	0.031	0.110	-	0.024	0.024	-	0.117	0.007	0.110
Dominican Republic	2.254	2.195	0.059	-	1.057	1.057	-	1.197	1.138	0.059
Puerto Rico	12.950	12.650	0.300	-	0.350	0.350	-	12.600	12.300	0.300
U.S. Virgin Islands	0.705	0.705	-	-	0.321	0.321	-	0.384	0.384	-
Br. Virgin Islands	0.013	0.013	-	-	-	-	-	0.013	0.013	-
Antigua	0.038	0.038	-	-	0.007	0.007	-	0.031	0.031	-
St. Kitts	0.022	0.022	-	-	0.004	0.004	-	0.018	0.018	-
Montserrat	0.008	0.008	-	-	-	-	-	0.008	0.008	-
Guadeloupe	0.140	0.140	-	-	-	-	-	0.140	0.140	-
Dominica	0.013	0.002	0.011	-	-	-	-	0.013	0.002	0.011
Martinique	0.161	0.161	-	-	-	-	-	0.161	0.161	-
St. Lucia	0.037	0.037	-	-	-	-	-	0.037	0.037	-
St. Vincent	0.017	0.008	0.009	-	-	-	-	0.017	0.008	0.009
Barbados	0.212	0.212	-	-	-	-	-	0.212	0.212	-
Grenada	0.025	0.025	-	-	-	-	-	0.025	0.025	-
Netherl. Antilles	1.550	1.550	-	-	0.900	0.900	-	0.650	0.650	-
Trinidad and Tobago	1.210	1.210	-	-	0.193	0.193	-	1.017	1.017	-
Guyana	0.361	0.361	-	-	0.175	0.175	-	0.186	0.186	-
Suriname	1.528	0.531	0.997	-	1.452	0.455	0.997	0.076	0.076	-
TOTAL	29.942	28.295	1.647	-	6.523	5.541	0.997	23.404	22.754	0.650

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.11. Caribbean Islands, Guyana and Suriname: production of electricity by type, by country (1976)
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
Bahamas	0.600	0.600	-	-	-	-	-	0.600	0.600	-
Cuba	7.198	7.145	0.053	-	1.205	1.205	-	5.993	5.940	0.053
Cayman Islands	0.037	0.037	-	-	-	-	-	0.037	0.037	-
Jamaica	2.378	2.233	0.145	-	0.975	0.975	-	1.403	1.258	0.145
Haïti	0.209	0.050	0.159	-	0.025	0.025	-	0.184	0.025	0.159
Dominican Republic	2.690	2.515	0.175	-	1.170	1.170	-	1.520	1.345	0.175
Puerto Rico	17.150	16.830	0.320	-	0.330	0.330	-	16.820	16.500	0.320
U. S. Virgin Islands	0.720	0.720	-	-	0.323	0.323	-	0.397	0.397	-
Br. Virgin Islands	0.012	0.012	-	-	-	-	-	0.012	0.012	-
Antigua	0.047	0.047	-	-	0.007	0.007	-	0.040	0.040	-
St. Kitts	0.023	0.023	-	-	0.004	0.004	-	0.019	0.019	-
Montserrat	0.009	0.009	-	-	-	-	-	0.009	0.009	-
Guadeloupe	0.190	0.190	-	-	-	-	-	0.190	0.190	-
Dominica	0.015	0.002	0.013	-	-	-	-	0.015	0.002	0.013
Martinique	0.194	0.194	-	-	-	-	-	0.194	0.194	-
St. Lucia	0.045	0.045	-	-	-	-	-	0.045	0.045	-
St. Vincent	0.017	0.007	0.010	-	-	-	-	0.017	0.007	0.010
Barbados	0.228	0.228	-	-	-	-	-	0.228	0.228	-
Grenada	0.028	0.028	-	-	-	-	-	0.028	0.028	-
Netherl. Antilles	1.600	1.600	-	-	0.850	0.850	-	0.750	0.750	-
Trinidad and Tobago	1.367	1.367	-	-	0.080	0.080	-	1.287	1.287	-
Guyana	0.398	0.398	-	-	0.186	0.186	-	0.212	0.212	-
Suriname	1.335	0.159	1.176	-	1.277	0.101	1.176	0.058	0.058	-
TOTAL	36.490	34.439	2.051	-	6.432	5.256	1.176	30.058	29.183	0.875

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.12. Caribbean Islands, Guyana and Suriname: installed capacity of power plants
(Thousands of kilowatts)

	Total capacity				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	842	750	92	-	475	475	-	367	275	92
1960	1660	1509	151	-	754	754	-	906	755	151
1970	5237	4879	358	-	1318	1138	180	3919	3741	178
1973	7695	7222	473	-	1820	1640	180	5875	5585	290
1974	9030	8543	487	-	1875	1695	180	7155	6848	307
1975	9084	8602	482	-	1879	1699	180	7205	6903	302
1976	9638	9156	482	-	1977	1797	180	7661	7359	302

<u>Source</u>: Data derived from U.N. statistics, primarily Ref. [7].

Table I.13. Caribbean Islands, Guyana and Suriname: installed capacity of power plants by type by country (1973)
(Thousands of kilowatts)

	Total capacity				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
Bahamas	242	242	-	-	-	-	-	242	242	-
Cuba	1576	1532	44	-	676	676	-	900	856	44
Cayman Islands	7	7	-	-	-	-	-	7	7	-
Jamaica	659	638	21	-	232	232	-	427	406	21
Haïti	75	43	32	-	18	18	-	57	25	32
Dominican Republic	547	451	96	-	210	210	-	337	241	96
Puerto Rico	3032	2937	95	-	70	70	-	2962	2867	95
U. S. Virgin Islands	239	239	-	-	64	64	-	175	175	-
Br. Virgin Islands	4	4	-	-	-	-	-	4	4	-
Antigua	18	18	-	-	2	2	-	16	16	-
St. Kitts	13	13	-	-	3	3	-	10	10	-
Montserrat	4	4	-	-	-	-	-	4	4	-
Guadeloupe	40	40	-	-	-	-	-	40	40	-
Dominica	5	2	3	-	-	-	-	5	2	3
Martinique	46	46	-	-	-	-	-	46	46	-
St. Lucia	13	13	-	-	-	-	-	13	13	-
St. Vincent	6	4	2	-	-	-	-	6	4	2
Barbados	67	67	-	-	-	-	-	67	67	-
Grenada	7	7	-	-	-	-	-	7	7	-
Netherlands Antilles	290	290	-	-	140	140	-	150	150	-
Trinidad and Tobago	334	334	-	-	50	50	-	284	284	-
Guyana	170	170	-	-	75	75	-	95	95	-
Suriname	301	121	180	-	280	100	180	21	21	-
TOTAL	7695	7222	473	-	1820	1640	180	5875	5585	290

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.14. Caribbean Islands, Guyana and Suriname: installed capacity of power plants by type, by country (1976)
(Thousands of kilowatts)

	Total capacity				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
Bahamas	255	255	-	-	-	-	-	255	255	-
Cuba	1705	1661	44	-	690	690	-	1015	971	44
Cayman Islands	16	16	-	-	-	-	-	16	16	-
Jamaica	685	670	15	-	230	230	-	455	440	15
Haïti	89	42	47	-	18	18	-	71	24	47
Dominican Republic	743	647	96	-	300	300	-	443	347	96
Puerto Rico	4338	4243	95	-	70	70	-	4268	4173	95
U. S. Virgin Islands	239	239	-	-	64	64	-	175	175	-
Br. Virgin Islands	4	4	-	-	-	-	-	4	4	-
Antigua	22	22	-	-	2	2	-	20	20	-
St. Kitts	13	13	-	-	3	3	-	-	10	10
Montserrat	4	4	-	-	-	-	-	4	4	-
Guadeloupe	50	50	-	-	-	-	-	50	50	-
Dominica	6	3	3	-	-	-	-	6	3	3
Martinique	55	55	-	-	-	-	-	55	55	-
St. Lucia	14	14	-	-	-	-	-	14	14	-
St. Vincent	9	7	2	-	-	-	-	9	7	2
Barbados	99	99	-	-	-	-	-	99	99	-
Grenada	7	7	-	-	-	-	-	7	7	-
Netherlands Antilles	290	290	-	-	140	140	-	150	150	-
Trinidad and Tobago	454	454	-	-	50	50	-	404	404	-
Guyana	180	180	-	-	85	85	-	95	95	-
Suriname	361	181	180	-	325	145	180	36	36	-
TOTAL	9638	9156	482	-	1977	1797	180	7661	7359	302

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table I.15. Caribbean Islands, Guyana and Suriname: energy consumption
(Millions of metric tons of coal equivalent)

	Total commercial energy		Liquid fuels	Gas fuels	Solid fuels	Primary[1/] hydro and geo electricity	Nuclear electricity	Fuelwood[2/]	Total primary energy	
	Aggregate	Per capita							Aggregate	Per capita
1950	12.935	0.771	12.063	0.635	0.091	0.146	-	N.A.	N.A.	N.A.
1960	19.822	0.950	18.515	1.023	0.069	0.215	-	N.A.	N.A.	N.A.
1970	43.365	1.694	40.001	2.488	0.150	0.726	-	N.A.	N.A.	N.A.
1973	52.385	1.946	49.030	2.434	0.140	0.781	-	3.061	55.446	2.060
1974	51.446	1.863	48.216	2.234	0.120	0.876	-	3.063	54.509	1.974
1975	49.349	1.742	46.294	2.038	0.137	0.880	-	3.069	52.418	1.850
1976	51.201	1.762	47.790	2.287	0.146	0.978	-	3.024	54.225	1.866

Source: Data derived from U.N. statistics, primarily Ref. [7].

N.A. = not available.

1/ Conversion factor: 1000 kW produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Calorific value: 3×10^6 Kcal/m^3.

Table I.16. Caribbean Islands, Guyana and Suriname: energy consumption by country (1973)
(Millions of metric tons of coal equivalent)

	Total commercial energy		Liquid fuels	Gas fuels	Solid fuels	Primary[1] hydro and geo electricity	Nuclear electricity	Fuelwood[2]	Total primary energy	
	Aggregate	Per capita (t.c.e.)							Aggregate	Per capita (t.c.e.)
Bahamas	1.418	7.464	1.413	-	0.005	-	-	-	1.418	7.464
Cuba	10.518	1.164	10.370	0.019	0.098	0.031	-	0.643	11.161	1.235
Cayman Islands	0.031	2.402	0.031	-	-	-	-	-	0.031	2.402
Jamaica	4.010	2.033	3.963	-	0.001	0.046	-	-	4.010	2.033
Haïti	0.185	0.042	0.131	-	-	0.054	-	1.607	1.792	0.407
Dominican Republic	2.880	0.649	2.852	-	0.001	0.027	-	0.788	3.668	0.826
Puerto Rico	12.384	4.196	12.242	-	-	0.142	-	-	12.384	4.196
U.S. Virgin Islands	4.586	55.928	4.586	-	-	-	-	-	4.586	55.928
Br. Virgin Islands	0.012	1.233	0.012	-	-	-	-	-	0.012	1.233
Antigua	0.230	3.379	0.230	-	-	-	-	-	0.230	3.379
Montserrat	0.009	0.776	0.009	-	-	-	-	-	0.009	0.776
Guadeloupe	0.205	0.598	0.205	-	-	-	-	0.006	0.211	0.615
Dominica	0.017	0.230	0.013	-	-	0.004	-	-	0.017	0.230
Martinique	0.346	1.009	0.346	-	-	-	-	0.004	0.350	1.021
St. Lucia	0.040	0.374	0.040	-	-	-	-	-	0.040	0.374
St. Vincent	0.024	0.236	0.020	-	-	0.004	-	-	0.024	0.236
Barbados	0.232	0.953	0.228	0.004	-	-	-	-	0.232	0.953
Grenada	0.028	0.296	0.028	-	-	-	-	-	0.028	0.296
Netherlands Antilles	7.535	32.201	7.535	-	-	-	-	-	7.535	32.201
Trinidad and Tobago	5.336	5.044	2.925	2.411	-	-	-	0.005	5.341	5.048
Guyana	0.874	1.153	0.874	-	-	-	-	0.006	0.880	1.161
Suriname	1.471	3.668	0.963	-	0.035	0.473	-	0.002	1.473	3.673
TOTAL	52.385	1.946	49.030	2.434	0.140	0.781	-	3.061	55.446	2.060

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Calorific value: 3×10^6 Kcal/m^3.

Table I.17. Caribbean Islands, Guyana and Suriname: energy consumption by country (1976)
(Millions of metric tons of coal equivalent)

	Total commercial energy		Liquid fuels	Gas fuels	Solid fuels	Primary[1/] hydro and geo electricity	Nuclear electricity	Fuelwood[2/]	Total primary energy	
	Aggregate	Per capita (t.c.e.)							Aggregate	Per capita (t.c.e.)
Bahamas	1.537	7.286	1.537	-	-	-	-	-	1.537	7.286
Cuba	11.617	1.227	11.444	0.028	0.118	0.027	-	0.643	12.260	1.295
Cayman Islands	0.036	2.558	0.036	-	-	-	-	-	0.036	2.558
Jamaica	4.036	1.962	3.966	-	0.001	0.069	-	-	4.036	1.962
Haïti	0.190	0.040	0.113	-	-	0.077	-	1.607	1.797	0.378
Dominican Republic	3.364	0.696	3.278	-	0.001	0.085	-	0.744	4.108	0.850
Puerto Rico	11.651	3.625	11.501	-	-	0.15	-	-	11.651	3.625
U.S. Virgin Islands	5.157	54.283	5.157	-	-	-	-	-	5.157	54.283
Br. Virgin Islands	0.012	1.027	0.012	-	-	-	-	-	0.012	1.027
Antigua	0.173	2.438	0.173	-	-	-	-	-	0.173	2.438
Montserrat	0.014	1.078	0.014	-	-	-	-	-	0.014	1.078
Guadeloupe	0.247	0.685	0.247	-	-	-	-	0.006	0.253	0.701
Dominica	0.022	0.284	0.014	-	-	0.008	-	-	0.022	0.284
Martinique	0.363	0.984	0.363	-	-	-	-	0.004	0.367	0.995
St. Lucia	0.040	0.366	0.040	-	-	-	-	-	0.040	0.366
St. Vincent	0.023	0.230	0.019	-	-	0.004	-	-	0.023	0.230
Barbados	0.240	0.974	0.235	0.005	-	-	-	-	0.240	0.974
Grenada	0.020	0.211	0.020	-	-	-	-	-	0.020	0.211
Netherlands Antilles	5.503	22.836	5.503	-	-	-	-	-	5.503	22.836
Trinidad and Tobago	4.657	4.272	2.403	2.254	-	-	-	0.004	4.661	4.275
Guyana	0.839	1.072	0.839	-	-	-	-	0.007	0.846	1.080
Suriname	1.460	3.355	0.876	-	0.026	0.558	-	0.009	1.469	3.376
TOTAL	51.201	1.762	47.790	2.287	0.146	0.978	-	3.024	54.225	1.866

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Calorific value: 3×10^6 Kcal/m^3.

Chapter II. Subregion 2: Venezuela

1. Present energy situation

Production of primary energy

Over the last 28 years, the Venezuelan energy situation has been largely dominated by the exploitation of national hydrocarbon reserves. The large over-production of oil, in comparison with the domestic consumption, has made it possible for Venezuela to export its surplus all over the world, but mostly to countries in Latin and North America.

Except for the production of gas (almost entirely devoted to the domestic market), the relevance of other energy sources in the overall energy balance has been negligible. However, future energy strategies will modify this situation, increasing the share of the other energy sources in the energy production sector. This strategy has been partially applied in the past few years, and the trend is discernible in the data on energy production in the period 1973-77 shown in Table II.1.

From the same table, it can be seen that in five years (1973-77) the overall production of commercial energy dropped by some 30 per cent, attributable solely to a drop in oil production. The production of other forms of primary energy remained at the level of previous years (as for gas) or even increased (as for hydroelectricity generation and coal extraction).

Up until the beginning of the '70s, the annual production of oil increased constantly, the annual growth rate being about five per cent over a period of 20 years. Almost until the beginning of the '70s, Venezuela supplied the bulk of the oil imported by other Latin American countries: a part was supplied directly as crude oil, the rest exported as refined products by national refineries or through the Netherlands West Indies. This situation changed when Middle East oil became available at competitive prices: Venezuela's share in the Latin American market fell by about 50 per cent. Moreover, except for an increase in 1972, the lifetime of proven reserves dropped to about one or two decades (assuming the same oil extraction rate as in 1972) as against 70 years envisaged in the '50s. Given this situation the Government adopted an energy strategy oriented towards the conservation of the national non-renewable energy resources. Consequently, oil production decreased very rapidly after 1973 (31 per cent between 1973 and 1977), the annual rate of decrease being about nine per cent. On the other hand, Venezuela has always been very dependent on oil which still constitutes the predominant share of export revenues. This revenue is essential to the development of other industrial sectors, such as the extraction of iron-ore which is exported in large quantities. As a compromise, daily production was fixed at 2.2 million barrels. Data in Table II.2 on crude petroleum balance for the period 1973-77 show that this policy was maintained between 1975 and 1977 with operational flexibility (a fluctuation of less than seven per cent).

Oil production is located in the Maracaibo region, the Gulf of Venezuela, the Gulf of Vela (off the Paraguana Peninsula), and in the north-eastern part of the country. The bulk of production comes from the east-central part of Lake Maracaibo, and about 70 per cent of all oil extracted comes from off-shore wells (see Table II.2).

Some 44 per cent of the oil produced in 1976 (about one million barrels) was produced utilizing secondary and tertiary recovery. Such techniques as steam injection, flooding, and gas re-injection are used to increase the rate of exploitation. These methods have already been utilized in the past, despite the increased oil prices thereby incurred. However, given the policy of energy conservation, such methods will take on even more significance in future. As for gas production, the data reported in Table II.1. show that this remained approximately constant over the period 1973-77. Comparison of Table II.1. and Table II.8. (Venezuelan energy consumption) shows that the gas produced over the period 1973-76 was entirely devoted to the national market. Data in Table II.1. relating to gas production only show the amount of gas produced (and utilized) for fuel (or other industrial) uses. In reality, the production of gas was much higher: Table II.1. reveals only a fraction (estimated in 24 per cent) of the total gas production. The remainder was re-injected for secondary oil recovery (about 44 per cent) or flared (32 per cent).

The over-production of gas is associated with oil extraction. The gas extracted together with oil is not exported to other Latin American countries even though such a prospect, in principle, would appear very attractive. There are two main obstacles to utilizing surplus gas in a different manner:

(1) The possibility that diverting associated gas will ultimately bring about a drop in oil recovery. Consequently, only the gas flared at present would be available for better utilization in future.

(2) The difficulties of transporting gas not only all over the world, but also in Latin America.

In 1977, gas produced for the domestic market amounted to 11.3 billion cubic metres. In Venezuela coal extraction is limited because of the low domestic demand for this kind of fuel. However, in five years (1973-1977), the production of coal has more than doubled. In 1977, coal (0.11 million tons) represented less than 0.1 per cent of the national energy production. The bulk of national coal production stemmed from a small mine in the Tachira region. This coal was almost entirely supplied to cement factories located in the same area.

Owing to the large production of oil and gas, Venezuela did not need coal for fuel use. However, in order to meet the needs of the national iron and steel industry, some of the produced coal is now devoted to coke production, with good results. In future, greater efforts will be made in the same direction.

The utilization of hydroelectric energy has increased appreciably over the period 1973-76 (70 per cent in three years). The annual increment of production was about 19 per cent. Venezuela has large hydropower reserves but only a fraction (estimated between 2.5 and 5 per cent of the overall hydraulic potential) is utilized at present [6]. More than 80 per cent of the hydrological resources exploited come from the River Caroni, which, together with the River Santo Domingo, provides the bulk of hydroelectric energy.

In 1976, about 10.5 billion kWh were produced by means of hydropower. This rate corresponds to more than 45 per cent of all electricity generated. At present, Venezuela has no geothermal power plants, but some studies are being conducted to establish potential openings. The same applies to nuclear energy but, owing to the competitiveness of oil the possibilities of development in this sector are slight. As for the production of non-commercial primary energy (fuelwood, charcoal, bagasse, etc.) U.N. data [7] report a figure of 7.318 million cubic metres in 1975 and 1976, which has been reported in Table II.1.as 3.14 million t.c.e. utilizing a calorific value of 3.10^6 Kcal/m^3. Another reference [8] reports much lower figures, estimating bagasse production for fuel use at 330,000 tons (50 per cent of total production of cellulose from sugar-cane processing) and the production of fuelwood at 50,700 tons. In any event, the production of this kind of fuel is negligible in the total scenario of Venezuela energy production, as it constitutes 1.5 per cent of the total at the most.

Trade in energy and production of secondary energy

The global energy balance for Venezuela has been largely positive in the past few years. Table II.3.shows the export-import situation for the period 1973-76. The only negative item in the balance was due to the import of coal (mostly coke necessary for the iron and steel industry). However, this import represented less than 0.15 per cent of the total trade in energy. The remainder was represented by exports of petroleum, both crude and refined.

The total volume of petroleum exported declined over the period considered for reasons explained in the previous paragraph. The decrease was more than 30 per cent in only three years (1973-76).

In 1976 the Venezuelan exports amounted to about 503 million barrels of crude oil and 25 million barrels of liquid products coming from the natural gas processing plants. At the same time, refined petroleum exports accounted for about 263 million barrels (more than one third of the total petroleum exports).

As a consequence of the energy strategy devoted to the conservation of national resources, the drop in the export of crude oil (35 per cent between 1973 and 1976) was greater than the corresponding decrease for energy petroleum products (27.8 per cent).

Moreover, whereas the exports of crude petroleum dropped continuously, those of petroleum products fluctuated. Despite the negative trend between 1975 and 1976, the export of refined products increased by about 25 per cent as a result of the change in the international demand for these products.

In 1976 the export of hydrocarbons accounted for 73 per cent of the country's net income. As to the production of refined petroleum products, some 350 million barrels were processed in the refineries of the country in 1976, an increase of about 11 per cent over the previous year. The breakdown of the refined products was:

	Per cent
Gasoline and naphta	21
Heavy fuel oil	59
Diesel fuel and gas oil	13
Kerosene	2
Lubricants	1
Others	4

Production of electricity

Production of electricity over the period 1973-76 is shown in Table II.4. These data show a rapid increase in the electric energy generated (45 per cent in three years), the average annual growth rate over the same period being 13 per cent.

In Table II.5. the Venezuelan production of electricity is reported by type. Despite the wide availability of oil and gas (also for power generation), the hydroelectric sector expanded more rapidly than the corresponding sector of thermal power generation (59 per cent as against 29 per cent over the same period). Since the country has large exploitable hydrological reserves, the Government has preferred to exploit this renewable energy source rather than hydrocarbons.

The self-suppliers of electricity generated about 15 per cent of the global production. Most of these were refineries using cheap oil and/or gas for their purposes. Table II.6. reports the installed capacity of power plants by type. As this table shows, no hydropower station was utilized for private energy generation. Table II.6. also shows that no new power station for self supply was built between 1974 and 1976 (the same applied to refineries). It can thus be deduced that the efforts spent on exploiting hydropower were concentrated only in the public utilization sector.

Table II.7. shows data on the utilization of power plants by type. This table shows a decrease in the utilization of hydropower plants over the period 1973-76; this can be regarded as a consequence of the expansion of the sector. On the other hand, the thermal power stations enjoyed an increased coefficient of utilization over the same period. However, it always remained lower than the corresponding coefficient of the hydropower stations.

The average efficiency of the Venezuelan thermal power plants was one of the highest among the Latin American countries: about 3000 Kcal/kWh produced (i.e. a thermal efficiency of 28.5 per cent).

Consumption of energy

Energy consumption increased by 15.5 per cent between 1973 and 1976, growing at 4.9 per cent per year. This figure is not particularly high, if compared with the annual growth rate over the period 1950-1973 (8.2 per cent). From Table II.8 showing the energy consumption over the period 1973-76, it can be seen that between 1974 and 1975 consumption even decreased. This fact can be explained by the fact that more than 50 per cent of the global energy consumption devolved upon the energy sector, with particular regard to the oil extraction. In fact, looking at oil production in 1974 and 1975 (reported in Table II.2) it can be seen that extraction also decreased by 21.6 per cent (164 million barrels). Among the forms of commercial energy consumed, hydrocarbons obviously had the largest share (87 per cent). The consumption of hydroelectricity was about 10-12 per cent of the total, the remainder being covered by solid fuels.

The consumption of liquid fuels increased by about 20 per cent in three years (1973-76), but at an uneven annual growth rate (between 1974 and 1975 consumption decreased). The consumption of gas and solid fuels remained approximately constant, while the consumption (in this case equal to the production) of hydroelectric energy increased by 70 per cent over the same period. In 1976 the overall energy consumption was as follows:

	Per cent
- Energy sector	50
- Transportation	24.9
- Industrial	18.5
- Residential and commercial	5
- Others	1.6

2. National energy resources

Venezuela has had the largest proven oil reserves of the Latin American countries for decades. The recent Government limitations on oil extraction are a measure designed to extend well-life and to permit long-term well exploitation.

The prospects for gas are positive and in future suitable means of transportation will permit its export. Hitherto, coal reserves have not yet been adequately exploited mainly because of the competitiveness of oil, the extraction of which absorbed most of the investments in the energy sector. However, extensive coal reserves could grant the country the chance to achieve independence in this sector. Venezuela also has a large hydroelectric potential. Exploitation of this energy resource on a large scale has already started. Prospects are very good. The energy resources of the country are examined in greater detail below.

Petroleum reserves

At present, oil is considered the wealth of Venezuela; however, estimated reserves constitute only 43.4 per cent of the total estimated energy reserves of the country. Also taking gas reserves into account, this share rises to 63.4 per cent (by way of comparison present hydrocarbon production is about 98 per cent of the total energy production).

At present, petroleum production is centred upon the northern part of the country, the region in which the remaining estimated oil reserves are also located. In January 1973 these reserves were shown to be of the order of 14 billion barrels [9]. Other updated sources [11, 1, 8, 10] quote a figure of some 18 billion. These figures seem likely to increase as exploratory activities continue to expand. About 45,000 km of off-shore seismographic work was completed in 1978 and on this basis exploratory drilling will start soon. This exploration should not require too much time or great expenditure since the previous geological survey indicated a number of very large, and relatively shallow, deposits which can be tapped with a few wells.

Priorities have been established in respect of exploration. The first area lies off the Orinoco Delta in the north-eastern part of the continental shelf of Venezuela. The others are in the Gulfs of Venezuela, de la Vela, de Triste and de Paria. Since all these structures are off shore, special equipment such as drillships, mobile drilling rigs, and jack-up rigs, will be used.

Beside these oil reserves, Venezuela has another huge reserve of hydrocarbons which normally is not included in the official data. In a belt of 50,000 square km (700 km x 70 km) to the north of the Orinoco River there is a series of extra-heavy oil accumulations. An evaluation of these reserves has already been made. Ref. [9] gives a very conservative figure of 700 billion barrels. However, the other references considered [11, 12, 8], including semi-official data of the Venezuelan Ministry of Energy and Mines, present a figure of about 2,000 billion barrels. A small amount of the lightest oil of this so-called "faja petrolifera" have already been extracted in some oil fields bordering the "faja". However, production slumped drastically when the pumping of heavy oil started.

More than one half of the area has been prospected in the last years using seismographic methods. The oil was found to be distributed continuously along the oil belt, with about 50 per cent of the reserves concentrated in the eastern third of the region.

Exploitation of these reserves presents two kinds of problems: the first connected with extraction, the second with up-grading the oil. The extra-heavy crude oil has a very high viscosity which negatively affects the rate of production. Different methods can be used to eliminate the problem (injection of steam or viscosity-reducing solvents), but the energy consumption amounts to some 15 per cent of total energy value of the recovered oil. The viscosity also reduces the recovery efficiency of the wells which, in this case, is usually less than 10 per cent, unless external energy is introduced (e.g. fluid injection). Moreover, owing to the presence of sand, pumps capable of handling large amounts of sand mixed with oil have to be used.

In terms of chemical composition, Orinoco oil has a high sulphur content (between two and five per cent) and heavy metals content (vanadium plus nickel varying from 200 to 600 ppm). The content of asphaltenes (which are among the heaviest components in oil) is also very high. For commercial purposes, this oil has to be upgraded by adding hydrogen (hydrocracking) or coking. Both methods present problems due to the catalyst poisoning effect caused by the present of heavy metals and handling the coke produced.

For these reasons, the exploitation of these oil reserves is connected with future developments and the improvement of production techniques. It is unlikely that the Orinoco extra-heavy oil will be utilized in the near future.

Gas reserves

Venezuelan gas reserves are estimated to be about one half of the oil reserves (both expressed as t.c.e.). Hitherto oil has been always preferred to gas mainly because of the transportation problems. Proven gas reserves are of the order of one thousand billion cubic metres (b.c.m.). Ref. [9] gives a value of 980 b.c.m. References [6, 10, 8, 1] present very similar figures of about 1190 b.c.m. These reserves should cover a period of 31 years referring to the total 1975 production. However, about 44 per cent of this production was re-injected into the oil fields. If only the real consumption of gas (1975) is considered, the reserves should cover some 24 years more than the first period cited.

Coal reserves

Even though coal production has been less than 0.1 of the total energy production, the estimated coal reserves are of the same order of magnitude as other more important sources, such as oil or natural gas. Coal reserves are estimated to be some 19 per cent of the total energy reserves.

Among the three potential coal-rich areas (Zulia, Labatera and Naricual) only one (Naricual) has been conveniently explored. For this reason most of the proven reserves (amounting to nearly 10.8 million tons) have been found in that area.

However, the most promising coal-rich region is in the state of Zulia, in the north-western part of the country, close to the town of Maracaibo and with easy access to the sea. Exploratory studies gave a figure varying between 750 and 1,550 million tons according to the depth of extraction (400 or 900 m). The latter figure (1,550 million t.c.e.) was utilized to calculate the share of coal reserves in the total energy reserves.

Hydroelectric reserves

Hydroelectric potential in Venezuela is one of the highest in Latin America. Various sources quote completely different estimates, according to the different concepts of "economically exploitable hydroelectric potential" which are strictly dependent on fluctuations in oil prices. In Ref. [6] hydroelectric reserves are estimated to be 16,185 MW divided among 2,862 MW in plants under construction and 13,565 MW in planned plants. Ref. [10] gives a global figure of 45,000 MW, of which 20,000 are economically exploitable. The hydrological potential is divided among the rivers of Venezuela as follows:

	Megawatts
Caroni river	13,175
Caura river	2,520
Uribante river	900
Santo Domingo river	240
Caparo river	350
Other rivers	2,815

Ref. [8] reports the capacity figure approved by the National Council for Energy: 25,000 MW.

The highest estimate has been made by CEPAL [13] which quotes an economically exploitable potential of about 50,000 MW (the original figure was 304 thousand GWh per year).

Geothermal reserves

In Venezuela not too much interest has been shown in the study of geothermal sources of energy. Only in the past few years has the possibility of exploiting this form of energy stimulated one of the electricity companies to start investigations. In the area of El Pilar-Casanay, some basic explorations were carried out and positive results obtained. However, so far no data are available on the potential energy reserves of Venezuela in this sector.

Uranium reserves

No investigations have been carried out in Venezuela in order to evaluate the energy potential of nuclear fuel reserves.

Non-commercial energy reserves

By virtue of its geographic location, Venezuela could in principle exploit solar energy both directly through devices designed to transform the primary energy input into exploitable energy, and indirectly through photosynthesis into biomass. However, in the past, these resources have always been neglected because national efforts have been concentrated on the hydrocarbons sector. Only in the past few years has the situation slightly changed; however, prospects in the non-conventional energy sector have still to be evaluated.

3. National energy policies

As explained in the previous paragraphs, the Venezuelan economy is largely dependent on oil production and trade, as oil exports account for 73 per cent of total national exports (1976 datum).

Having been an oil-producing country for the past 30 years, the Government has adopted a policy based on maximizing oil revenues and reducing dependence on the foreign oil companies which up until 1976 controlled most of the oil production.

The first aim was reached by slowly increasing oil production and the price per barrel (more rapidly after 1970 together with the other OPEC countries). The second goal has been accomplished by granting no new concessions since 1957, and by speeding up the process of state control through the national oil company. The last step in this policy was the nationalization of the oil industry (in 1976) through the vehicle of the Petroleos de Venezuela S.A. (Petroven), the company set up to manage and operate oil companies in the country.

Prior to nationalization, the oil companies reacted to increases in tax rates and the cut in concessions by reducing capital investments. The outcome was limited exploratory activities which led to a decline in the proven oil reserves of Venezuela.

After 1976 Petroven launched a new exploratory programme as part of a larger programme of expansion. $20 billion have been budgeted over a 10-year period (1977-1986). However, of this sum only 20 per cent or less will be devoted to exploratory activities. Until 1982, exploration funds will be $245 million per year, increasing to $350 million by 1983. By way of comparison, in 1978 the funds budgeted for production amounted to $720 million. This figure will be increased to $1,229 million in 1982 and to over $2 billion in 1986. This limited assignment of funds to exploration can be justified by the fact that most of the probably oil-rich structures already identified are rather large and shallow, and consequently their investigation calls for only a few wells. On the other hand, Petroven anticipates finding other new oil deposits, the exploitation of which will require high investment.

In the long run, Petroven also envisages exploiting the large extra-heavy oil reserves in the Orinoco belt, but the technical and economic problems associated with the extraction and up-grading of the oil seem far from being solved. However, a Petroven research group is working on these specific problems.

In general, the present energy policy pursued by Venezuela is characterized by the following goals:

- Limitation of oil extraction. This measure has already been adopted, the maximum production limit being 2.2 million barrels per year. This should lead to an increase in the availability of reserves.
- Greater use of the renewable energy sources and alternatives to oil. Many efforts are now concentrated on the exploitation of the hydroelectrical resources. The ambitious programme aims at producing 75 per cent of the total electricity generation by means of hydropower, and prospects are positive. The trend of the past years shows a real interest in this sector. The situation in the coal sector has also changed and will change even more rapidly in the future. Mining is expected to rise up sharply in order to utilize coal both for the iron and steel industry and for power production. However, the latter application could have some implications for the environment.
- Implementation of the exploratory activities in all the energy sectors. The main interest is obviously concentrated on oil, but other sectors such as the coal, gas or geothermal sectors will also benefit from the new trend.

4. Future energy demand

Various extrapolations as to future energy consumption in Venezuela, derived from different sources, are presented. As usual, they differ appreciably from each other.

The annual energy consumption growth rate between 1950 and 1975 was 6.5 per cent. Assuming this as the constant growth rate for the future, estimated consumption will be 65 t.c.e. in 1985 and 168 t.c.e. in 2000. By way of comparison, the corresponding annual growth rate in the period 1974-76 was negative, -4.9 per cent. However, this figure derives from the particular energy situation of the country at that time (see Section 1 - Consumption of energy).

Ref. [13] estimates an energy consumption figure for the year 2000 very similar to that presented above. This figure is 167 t.c.e.: oil and derivates 33.6 per cent; gas 49.6 per cent; coal 6.9 per cent, and primary hydroelectricity 9.9 per cent.

A third extrapolation, likewise based on 1950-74 energy consumption data, is presented in Ref. [5]. Based on an annual growth rate of 5.68 per cent, envisaged consumption will be 60 t.c.e. in 1985 and 138 t.c.e. in 2000. A forecasting model elaborated by the same researchers gives a different figure for the year 2000: 82 t.c.e. The average annual growth rate which can be assumed therefrom is 3.5 per cent. Following the general trend towards a lower energy demand scenario, the same researchers presented another forecast giving a figure of 46 t.c.e. in 1975 and 68 t.c.e. in 2000, with an average annual growth rate of 2.7 per cent. The figures given for year 1985 only vary by a factor of 1.4 (related to the maximum and minimum), while the corresponding figures for the year 2000 differ by a factor of 2.5.

In terms of envisaged electricity consumption, Ref. [5] gives figures of 48 billion kWh in 1985 and 117 billion kWh in 2000, with an annual growth rate of 7.11 per cent. Ref. [13] presents a very similar figure for year 2000 of 121 billion kWh, 55 per cent generated by means of hydropower and 45 per cent by gas-fired power plants.

The cumulative future demand of energy (the sum of the total future energy demand from 1979 on) can be derived from the above figures. This value ranges between 253 and 336 t.c.e. if the sum is extended till 1985, and between 1096 and 2024 t.c.e. if the sum is extended till 2000. In the first case, the spread represents a factor of 1.33; in the second a factor of 1.85.

5. Future national energy problems

As shown in the last paragraph, the country's cumulative energy demand up to year 2000 was estimated as ranging between 1,000 and 2,000 million t.c.e.

On the other hand, it was also shown that the proven hydrocarbon reserves were of the order of 4,000 million t.c.e. In terms of energy supply, this means that Venezuela could be self-sufficient even after the year 2000. However, the solution to this problem is not so simple, since most of the oil is exported and the revenue thus acquired is essential to the Venezuelan economy. Even with the recent cut in oil production, the present estimated reserves should just last until the year 2000.

On the other hand, Venezuela has large hydrocarbon reserves (the extra-heavy oil of the "faja") which could be exploited as soon as certain technical and economic problems are overcome (this is expected before the year 2000).

In the light of the foregoing it can be concluded that the national energy problems facing the country in the future will be connected with:

- Stepping up exploratory activities in order to establish greater hydrocarbon reserves;
- Conducting studies and researches into the oil of the "faja" so as to ensure its marketability;
- Diversifying the national energy structure, which at present is mainly based on hydrocarbons, in favour of other national energy sources such as coal (potential reserves of the order of 1000 million t.c.e.) and hydroelectricity which in principle could account for the total national electricty production even in the year 2000; and
- Diversifying the national industry which at present is almost entirely concentrated on extracting and processing hydrocarbons.

Table II.1. Venezuela: production of primary energy
(Millions of metric tons of coal equivalent)

	Total primary commercial energy Aggregate	Solid fuel	Liquid fuel	Gas	Primary[1/] hydro and geo electricity	Nuclear electricity	Fuelwood[2/]	Total primary energy Aggregate
1950	116.089	0.001	114.509	1.488	0.091	-	N.A.	N.A.
1960	226.631	0.035	220.409	6.135	0.052	-	N.A.	N.A.
1970	302.361	0.040	288.160	11.975	2.186	-	N.A.	N.A.
1973	282.397	0.050	263.299	16.386	2.662	-	2.963	285.360
1974	254.192	0.057	234.196	16.863	3.076	-	3.050	257.242
1975	204.205	0.060	184.080	16.228	3.837	-	3.140	207.345
1976	202.247	0.089	180.719	16.901	4.538	-	3.140	205.387
1977		0.110	179.002	16.433		-	3.140	

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kWh produced correspond to 0.43 t.c.e. (efficiency of 23.1 %).

2/ Calorific value: $3x10^6$ $Kcal/m^3$.

Table II.2. Venezuela: crude petroleum balance and refinery capacity
(Millions of metric tons of coal equivalent)

	Total petroleum production (including off shore)	Off shore petroleum production	Imports	Exports	Additions to Stocks	Apparent Supply	Refinery capacity
1950	77.897	N.A.	-	64.460	0.440	12.997	13.490
1960	149.372	N.A.	-	104.628	0.075	44.669	52.370
1970	194.306	128.050	-	127.591	-0.530	67.245	71.210
1973	175.776	140.543	-	110.907	-0.785	65.654	77.750
1974	156.167	108.437	-	92.450	-0.001	63.718	77.750
1975	122.400	85.000	-	76.718	-0.540	45.142	77.750
1976	120.153	85.000	-	71.565	-0.512	49.100	77.750
1977	119.000						

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table II.3. Venezuela: energy trade
(Millions of metric tons of coal equivalent1/)

	1973	1974	1975	1976
Crude petroleum				
Import	-	-	-	-
Export	163.033	135.901	112.775	105.200
Energy balance (Exp.-Imp.)	+163.033	+135.901	+112.775	+105.200
Energy petroleum products				
Import	0.016	0.002	-	-
Export	78.938	71.745	45.504	57.728
Energy balance (Exp.-Imp.)	+78.922	+71.743	+45.504	+57.728
Natural gas				
Import	-	-	-	-
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-	-	-	-
Solid fuel				
Import	0.324	0.208	0.266	0.240
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-0.324	-0.208	-0.266	-0.240
TOTAL				
Import	0.340	0.210	0.266	0.240
Export	241.971	207.646	158.279	162.928
Energy balance (Exp.-Imp.)	+241.631	+207.436	+158.013	+162.688

Source: Data derived from U.N. statistics, primarily Ref. [7], except for petroleum products obtained as difference.

1/ 1 ton petroleum = 1.47 t.c.e.

Table II.4. Venezuela: production, trade and consumption of electricity
(Thousand millions of kilowatt hours)

	Total production	Import	Export	Total consumption	Per capita consumption (in kWh)	Per capita installed capacity (in kW)
1950	1.220	-	-	1.220	229	0.066
1960	4.651	-	-	4.651	601	0.175
1970	12.631	-	-	12.631	1229	0.313
1973	16.077	-	-	16.077	1425	0.298
1974	18.222	-	-	18.222	1567	0.377
1975	21.179	-	-	21.179	1766	0.392
1976	23.276	-	-	23.276	1883	0.419

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table II.5. Venezuela: production of electricity by type
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	1.220	1.046	0.174	-	0.667	0.667	-	0.553	0.379	0.174
1960	4.651	4.556	0.095	-	1.990	1.990	-	2.661	2.566	0.095
1970	12.631	8.527	4.104	-	2.239	2.193	0.046	10.392	6.334	4.058
1973	16.077	9.910	6.167	-	2.400	2.400	-	13.677	7.510	6.167
1974	18.222	11.091	7.131	-	3.000	3.000	-	15.222	8.091	7.131
1975	21.179	12.281	8.898	-	3.000	3.000	-	18.179	9.281	8.898
1976	23.276	12.752	10.524	-	3.000	3.000	-	20.276	9.752	10.524

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table II.6. Venezuela: installed capacity of power plants
(Thousands of kilowatts)

	Total capacity				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	350	315	35	-	180	180	-	170	135	35
1960	1353	1220	133	-	523	523	-	830	697	133
1970	3220	2312	908	-	532	519	13	2688	1793	895
1973	3357	2390	967	-	478	478	-	2879	1912	967
1974	4391	2806	1585	-	624	624	-	3767	2182	1585
1975	4705	2900	1805	-	624	624	-	4081	2276	1805
1976	5176	2931	2245	-	624	624	-	4552	2307	2245

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table II.7. Venezuela: utilization of installed electric generating capacity
(Kilowatt hours produced per kilowatt)

	Total capacity				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	3486	3321	4971	-	3706	3706	-	3253	2807	4971
1960	3438	3734	714	-	3805	3805	-	3206	3681	714
1970	3923	3688	4520	-	4209	4225	3538	3866	3533	4534
1973	4789	4146	6377	-	5021	5021	-	4751	3928	6377
1974	4150	3953	4499	-	4808	4808	-	4041	3708	4499
1975	4501	4235	4930	-	4808	4808	-	4455	4078	4930
1976	4497	4351	4688	-	4808	4808	-	4454	4227	4688

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table II.8. Venezuela: energy consumption
(Millions of metric tons of coal equivalent)

	Total primary commercial energy		Solid fuel	Liquid fuel	Gas	Primary[1] hydro and geo electricity	Nuclear electricity	Fuelwood[2]	Total primary energy	
	Aggregate	Per capita (t.c.e.)							Aggregate	Per capita t.c.e.
1950	4.871	0.914	0.002	3.290	1.488	0.091	-	N.A.	N.A.	N.A.
1960	13.154	1.699	0.036	6.931	6.135	0.052	-	N.A.	N.A.	N.A.
1970	25.518	2.483	0.352	11.005	11.975	2.186	-	N.A.	N.A.	N.A.
1973	33.170	2.941	0.374	13.750	16.384	2.662	-	2.963	36.133	3.203
1974	34.998	3.009	0.265	14.786	16.871	3.076	-	3.050	38.048	3.271
1975	34.803	2.901	0.326	14.409	16.231	3.837	-	3.140	37.943	3.163
1976	38.323	3.100	0.329	16.555	16.901	4.538	-	3.140	41.463	3.355

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kWh produced correspond to 0.43 t.c.e. (efficiency of 23.1 %).

2/ Calorific value: $3x10^6$ Kcal/m^3.

Chapter III. Subregion 3: Colombia

1. Present energy situation

Production of primary energy

The evolution of the Colombian energy situation over the past few years differed from that of the other Latin American countries. Over the period 1973-77, the total production of primary energy in Colombia decreased by 6.3 per cent, which corresponded to a negative average annual growth rate of -1.54 per cent. Details of this negative trend in energy production are shown in Table III.1. concerning the production of commercial and non-commercial energy. The drop in the production of hydrocarbons (both as crude petroleum and gas) which was not compensated for by the increase in coal extraction and hydroelectricity generation was the main cause of the reduced energy-output.

Colombia has been an established oil-producing country for more than 50 years, and the most significant data about the oil production and trade for the period 1973-76 are shown in Table III.2. Whereas oil production experienced appreciable growth during the '60s with an annual growth rate of 4.3 per cent (an increase of more than 50 per cent in ten years), production dropped rapidly in the period 1970-74, whence it has dropped to level of 1960.

Oil now represents about 50 per cent of the total production of commercial energy, as against 60 per cent in 1974. The decrease in oil extraction can be mainly attributed to two factors:

- Depletion of the national oil reserves
- Little effort devoted to discovery of new oil fields.

At present, only some 20 per cent of the envisaged oil producing regions have been effectively prospected.

As a consequence Colombia started to import oil in 1976 whereas only two years previously it had been an oil exporter. However, since 1974 the prospecting activities have increased considerably: more than 900 new exploratory wells have been drilled and new exploitable reserves discovered. In 1977, crude oil production was about 77 million barrels compared with 1.6 billion cubic metres of natural gas which is equivalent to 20 per cent of the total national production of hydrocarbons. Gas extraction started on an industrial scale in the late '50s and within a decade (between 1960 and 1970) production had increased by a factor of seven reaching approximately the present figure. However, similar to oil, gas production has decreased at about 3 per cent per year since 1974.

In terms of coal and solid fuel in general, Colombia has the largest potential coal reserves in Latin America. This notwithstanding, coal production represents only about 15 per cent of the national production of commercial energy. As can be seen from Table III.1, the trend in most recent years has been to increase the coal production. This was the outcome of:

- Increased international demand for coke in the steel and iron industry; and
- Re-assessment of coal as fuel following the global oil crisis and the drop in the national oil production.

Since 1970, coal extraction has increased at an average annual growth rate of 4.9 per cent, and in 1977 coal production reached 3.7 million tons. This period of growth followed on a stagnant period in the '60s when the annual growth rate was almost negligible.

However, it is in the production of hydroelectric energy (the most rapidly increasing sector together with coal) that the highest annual growth rate (7.6 per cent) has been achieved among the primary energy sources in the period 1973-76. This increase was in parallel with that in the electricity production sector. In the past few years, the share of hydroelectric energy remained approximately constant (65 per cent), and all hydropower sources have been utilized to the fullest extent for the generation of electricity. In 1977, total hydroelectric energy production amounted to about 10^{10} kWh in 1977. At present, Colombia has no nuclear power stations.

As for fuelwood production, Table III.1. presents some data for the period 1973-77: the figure shown is the same every year. Consequently, the figure must be regarded as an indicative rather than an exact value, owing to the difficulties of collecting data. Fuelwood production represents about one quarter of the total commercial and non-commercial energy production: 8.57 million tons of coal equivalent (this corresponds to an original value of 22 million cubic feet). This figure is very high, particularly when compared with production figures for coal (3.7 million t.c.e.) and hydroelectric energy (10.08 billion kWh) in the same year (1977).

Trade in energy and production of secondary energy

The energy balance for Colombia showed a clear negative trend in the period 1973-76. Exports slumped by 54 per cent, while imports increased by about 1.8 million t.c.e., almost equal to energy exports in 1976. The total energy balance and its breakdown for the period 1973-76 are shown in Table III.3.

As a coal producer, Colombia has always exported coal: however, there have been major fluctuations even in the short period under consideration, a feature ascribable to the instability of both national and international markets. In any event, the coal trade has always represented but a small fraction of the total trade in energy. The greatest share is represented by oil, both as crude and its derivatives.

Colombia exported oil up until 1974. In 1975, national oil production was wholly consumed by the domestic market, and by 1976 Colombia had started to import oil. Since crude oil was the main product exported (insofar as the energy sector is concerned), this change greatly affected the overall energy balance. The only positive contribution to exports (apart from coal which constituted only a small fraction) that remained were the energy derivatives of oil (99.7 per cent of the energy exports in 1977).

However, even in the latter sector, exports decreased (by 16 per cent between 1973 and 1976) and imports increased. This situation came about as a result of an increase in domestic demand which was not absorbed by a corresponding increase in national refinery capacity. From Table III.2. it can be seen that refinery capacity remained unchanged between 1974 and 1976.

However, in order to limit the imports arising from the growth in domestic demand, some new refineries are scheduled for completion in the near future. It is estimated that by 1980 refinery capacity will have increased to 10.7 million tons of crude petroleum.

In 1977 Colombia imported crude oil, mainly from Venezuela. Other petroleum derivatives (motor gasoline, kerosene, etc.) were imported from the Netherlands Antilles, Brazil, Mexico and Venezuela. In the same year Colombia exported fuel oil to the United States, Canada, Mexico, Bahamas and Venezuela.

Production of electricity

The electric energy sector in Colombia has grown rapidly over the past three decades. More recently, electricity generation increased by more than 20 per cent in only three years (1973-76). The increase was brought about totally by the public service which increased production by 25 per cent over the same period. The self-suppliers of electricity are mainly refineries and similar industrial plants. Since no new refineries were built between 1973 and 1976, the independent production of electricity remained more or less constant over this period. Table III.5.shows data relating to the production of electricity, by type, between 1973 and 1976. About two-thirds of the total electricity was produced by hydropower plants. This sector showed a particularly high increase (24.5 per cent) over the same period, while thermal generation increased by 16.8 per cent. This increment can be seen in Tables III.5. and III.6., the latter table showing data on the installed capacity of power plants. These figures show a development towards the exploitation of renewable resources of national energy (hydropower) and the trend towards saving national non-renewable resources, at least in the electricity production sector. As further proof, Table III.7. shows data relating to the utilization of power plants: hydropower stations have a higher coefficient of utilization (except for electricity self-suppliers).

Consumption of energy

Between 1950 and 1970, the Colombian energy consumption increased rapidly at an annual growth rate of 10.34 per cent: in the period 1973-76, this figure was 4.5 per cent. Data about energy consumption in Colombia are reported in detail in Table III.8. Owing to the high consumption of fuelwood, the per capita consumption of commercial energy differs appreciably from the per capita total consumption (0.8555 t.c.e. versus 1.207 t.c.e. in 1976). Among the sources of commercial energy, hydrocarbons (liquid and gaseous fuels) showed the largest share (57 per cent), followed by hydropower energy (26 per cent) and coal (17 per cent).

Despite the reduction in the production of oil and gas, domestic consumption of hydrocarbons increased by 17 per cent in the period 1973-76. Hydropower energy consumption increased by 25 per cent, following the same trend as electricity consumption.

As for solid fuel, coal consumption increased by about 20 per cent, showing the possibility of substituting - in part - other liquid or gaseous fuels. Hitherto, coal demand has always been lower than envisaged for two reasons:

- Low development of the national iron and steel industry which could utilize a large fraction of the coke production; and

- Low competitiveness of coal compared with oil, even on the domestic market.

The latter factor, however, will change in the near future and is already changing.

In 1976 the breakdown of energy consumed was as follows.

	Percentage
Electricity generation	12
Industry	38
Transportation	40
Domestic use	5
Other uses	5

2. National energy resources

The energy situation in Colombia in the immediate future can be regarded with moderate optimism. The hydrocarbons reserves should allow Colombia to achieve self-sufficiency (or to remain only slightly dependent on nearby oil-exporting countries) in respect of oil and gas. The accomplishment of this goal will also depend on the capacity to utilize locally available energy sources currently other than oil.

The country has good coal production prospects: proven reserves are large enough to make the country a substantial exporter of coal. Equally favourable prospects are to be expected for the exploitation of the hydroelectric potential since Colombia has large reserves in this field.

Petroleum reserves

Estimates as to oil reserves have varied in the last few years depending on their authors. In 1973 reference [9] presented a figure of 1500 million barrels of oil. According to two other updated references (1977) envisaged oil reserves are much lower. Reference [6] presents a figure of about 500 million barrels. Reference [8] cites a figure of 530 million barrels: the original source of the latter figure is the Colombian Ministry for Mines and Energy which only takes into account proven reserves. Reference [1] gives a figure of about 4000 million barrels, of which 700 million barrels are economically recoverable. This value is closer to the other two references [8, 6]. If exploitation of these reserves ensues at the 1977 rate (about 50 million barrels per year), current proven oil reserves may be exhausted in about 10-15 years. However, at present, only about one-fifth of the expected oil-producing regions have been explored, and more intensive exploration operations were only launched in the last few years.

Gas reserves

Proven natural gas reserves seem to be of the order of 20-30 per cent of the total hydrocarbon reserves. A figure of 41.1 billion cubic metres of gas is presented in Ref. [8]. This value corresponds to about 30 per cent of the total estimated hydrocarbon reserves.

A higher figure is given by reference [9], 68 billion cubic metres, a figure which the same source claims to correspond to 20 per cent of the total oil and gas reserves.

Coal reserves

Of the Colombian energy reserves, coal has the largest share. In fact, Colombia disposes of about 60 per cent of the total coal reserves of Latin America, the main potential reserves being located in about 35 different sites spread all over the country.

The overall estimates of Colombian coal potential were started in 1951 and have been continuously updated. Initial calculations indicated proven reserves of about 200 million tons updated to 375 million in 1977 (data from the Mines and Energy Ministry) (see Ref. [8]). However, some estimates (Ref. [14]) indicated possible reserves some 100 times higher, yielding a figure of about 40,000 million tons. The main productive area is in the region of Guajira in the northern part of the country on the border with Venezuela. Major reserves of high-quality coal are concentrated in the area of El Cerrejon in the same region. This coal is bituminous, not cokable, with a high volatile (32-37 per cent) and low sulphur (0.52 per cent) content, suitable for export. The extraction of this coal should not be too difficult, as the coal is located in layers (more than one metre thick) at the surface level over a large area. Other coal-rich regions are on the Pacific coast and in the central region. The mines located in the latter region have good prospects as producers of cokable coal. However, these last potential sources have yet to be explored and fully assessed.

Colombia is the only Latin American country to date which disposes of coal with high, medium and low volatile contents in quantities suitable for large-scale exports. The quantities are: 33 per cent anthracite and semi-anthracite, 14 per cent bituminous coal with low and medium volatile content, and 53 per cent bituminous with high volatile content. Of this more than one half is suitable for coking.

Hydroelectric reserves

Colombia's potential hydroelectric reserves are among the largest in Latin America. According to Ref. [8] the potential reserves are of the order of 25,000 MW. In Ref. [6] the "planned" hydroelectric reserves are estimated at 23,350 MW. Even though the authors did not specify in detail the meaning of potential (or planned) reserves, this term should be taken to include all possible reserves which have been studied and proven economically exploitable. Other figures can be obtained relating in general to the total potential reserves, including the non-economically exploitable. In this case, Ref. [13] gives a value of 55,000 MW.

Although the capital investment and the time required to build a hydroelectric station are relatively high, the long-term prospects are favourable prospects for this sector and will enable Colombia to meet a large proportion of demand.

Geothermal reserves

Since 1968 geological investigations have been carried out in Colombia in the Caldas region. Preliminary investigation revealed that energy could be produced on a small scale. The result of the tests conducted in a pilot plant (3-10 MW) will determine the feasibility of adopting a geothermal energy exploitation programme.

Uranium reserves

No data are available on the Colombian nuclear fuel reserves.

Non-commercial energy reserves

The geographical position of the country is suited to the future exploitation of solar energy as soon as cheaper technologies are available. However, the humid climate will not permit too high a coefficient of insulation because of the diffusion effect of water vapour on the incoming radiation. In any event, miner applications of solar energy are already feasible.

Better suited to exploitation are the energy resources derived from biomass. Colombia already has a high production of non-commercial energy derived from fuelwood (see Table III.1). However, a more rational use of these energy resources could solve some of the present energy problems.

3. National energy policies

The energy balance of Colombia has switched rapidly in the last few years, with the country changing from an energy exporter to an energy importer. As a result, the country has been obliged to alter completely its energy strategy, which had previously been based on the simple exploitation of natural resources.

The new government strategy in this sector can be summarized as follows:

(1) Adoption of an appropriate exploratory programme devoted both to the detection of new energy resources and to the exploitation of energy potential thus discovered; and

(2) Initiation of a programme of substitution of other locally available forms of energy for oil derivatives.

As for the first point, a prospecting programme was approved, the goal being to establish about 80 wells per year. Furthermore, work on the detection of gas wells has increased following the good results obtained in the Guajira area. Major efforts are also being concentrated on the assessment and exploitation of coal reserves.

In particular, in the El Cerrejon area, investment in exploration operations was high (about 100 million pesos up to 1977), with a further 160 million pesos being earmarked for the completion of explorations in this area alone.

The studies on the utilization of hydropower are most interesting and productive, major efforts having been devoted to this sector. Hitherto economically exploitable reserves have been found, even though only 40 per cent of the country has been explored. Despite the absence of plans for the utilization of nuclear energy in the near future, a programme has been approved for the intensive exploration of limited areas thought to be rich in uranium.

As for the second point, the reduction of petroleum production lent impetus to the plans for the utilization of commercial energy sources other than oil. In any event, this new development programme will be based on a pricing policy which reflects the real costs of all energy alternatives. As a consequence of the oil crisis, Colombian coal used reached a competitive price compared with oil. This situation is even more favourable for Colombia because the other Latin American countries are relatively poorly endowed with this fuel.

However, the adoption of this coal policy will require synchronous infrastructural development which can be summarized as follows:

- Knowledge of potential coal reserves, mainly those that are economically exploitable;
- Knowledge of coal qualities (of importance in the light of possible coke exports);
- Stimulation and orientation of the domestic market towards the use of coal as a fuel, promoting the development of appropriate technologies for this purpose;
- Development and modernization of mines as bases for the establishment of a large-scale coal industry;
- Development of a research programme in order to limit the negative environmental impact of mining and industrial uses of coal;
- Creation and promotion of a national coal industry as an effective government tool;
- Creation of the necessary infrastructure, primarily in the transport sector (railways, ports, etc.); and
- Training of specialized personnel.

Apart from coal, gas was also scheduled as an oil-substitute, primarily after the Guajira fields had been discovered.

In the electric energy production sector, government policy has already favoured the exploitation of hydropower as a renewable energy resource. The data reported in Table III.6. showing electricity produced in the last few years confirm this trend. At present, some 65 per cent of the total electricity produced is generated by hydropower, and by 1985 this share should be even higher. It is estimated that it will attain a level of 85 per cent for electricity production, increasing at about ten per cent per annum. It is envisaged that eight new hydropower stations with a total capacity of 4500 MW will be in operation by that time.

4. Future energy demand

In the case of Colombia, as in other countries, different forecasters offer widely different estimates in respect of future energy consumption. During the period 1950-75, the average annual growth rate in energy consumption was 8.8 per cent.

This annual growth rate is rather high, and can be assumed to be the result of rapid developments in a developing country. It seems unlikely that Colombia can continue to develop at such a rate in the future. For the more recent past, the annual growth rate for energy consumption was only 2.25 per cent in the period 1974-76. Ref. [1] presents an estimate for energy consumption of 46 million t.c.e. in 1985.

A different extrapolation, based on data relating to the period 1950-75, was made by IIASA scientists [5]. The extrapolated consumption are 43 and 120 million t.c.e. for 1985 and 2000, respectively, the corresponding annual growth rate being about 4.8 per cent. The same researchers used a model to predict energy demand up to the year 2000. This figure was conceived in a so-called "high energy consumption scenario". In a "low scenario" the energy consumption for year 2000 was estimated to be 44 million t.c.e.

The annual growth rates derived from the last two figures are 4.0 per cent and 3.2 per cent respectively. From these rates it can be deduced that the energy demand for year 1985 will be 29 million t.c.e. in the high scenario and 27 million t.c.e. in the low scenario.

The figures presented for year 1985 differ only by a factor of 1.7 (referred to as the minimum and the maximum). The figures presented for the year 2000 differ by a factor of 3.7.

Extrapolations for electricity are reported by Ref. [5] (IIASA). At an annual growth rate of 8.67 per cent, the consumption for 1985 is estimated at 35.64 billion kWh and for the year 2000, 115.55 billion kWh.

The cumulative future demand of energy (i.e. the sum of the yearly future energy demand from 1979 on) can be deduced from the data given above. This figure, for the period 1979-85, varies between 149 and 223 million t.c.e. The difference between the two is 50 per cent. The integrated demand of energy for the period 1979-2000 varies between 676 and 1723 million t.c.e., and these figures present a factor spread of a factor 2.55.

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5. Future national energy problems

Despite the fact that Colombia has been an oil-producing and -exporting country for the last 50 years, it seems that it will have to import crude oil in future in order to meet growing domestic demand. The integrated demand of energy up to 2000 is assumed to lie between some 680 and 1700 million t.c.e. The estimated oil reserves are of the order of 700 million barrels (100 million t.c.e.). As a consequence, oil may only last a few years (unless new discoveries are made). The gap between the future envisaged production and consumption of energy could be bridged, using other energy resources of the country: the probable coal reserves should guarantee energy supplies for decades. In principle, all present and estimated future production of electricity could be achieved by means of hydropower. The country already produces large amounts of fuel of vegetable origin and has a large exploitable potential in this sector, while the geographical position of the country could permit the use of solar energy. However, since more than 50 per cent of the energy consumption is at present based on hydrocarbons, the use of any energy sources other than oil and gas requires time, a change in technology, and high investments. Furthermore, some of the available resources in the country still require an evolution of technology (e.g. solar), or their use is limited by economic constraints (e.g. hydropower) or other kinds of problems (e.g. the pollution problems caused by the use of coal).

In the near future, Colombia will have to solve two kinds of problems: the first connected with the present (and probably also future) partial lack of energy. This problem will be solved by importing hydrocarbons from other countries at ever increasing prices, or possibly through new possible oil discoveries. At the same time, Colombia will have to face the second problem of starting a policy of diversification of its own energy sources, thinking in terms of exploitation of the national energy resources available, and in terms of energy conservation.

Table III.1. Colombia: production of primary energy
(Millions of metric tons of coal equivalent)

	Total primary commercial energy Aggregate	Solid fuel	Liquid fuel	Gas	Primary[1/] hydro and geo electricity	Nuclear energy	Fuelwood[3/]	Total primary energy Aggregate
1950	N.A.	1.010	6.925	N.A.	0.385	-	N.A.	N.A.
1960	15.802	2.600	11.287	0.538	1.377	-	N.A.	N.A.
1970	25.156	2.750	17.032	1.950	3.424	-	N.A.	N.A.
1973	24.309	3.048	14.398	2.556	4.307	-	8.570	32.880
1974	23.745	3.266	13.203	2.475	4.801	-	8.570	32.316
1975	23.554	3.447	12.328	2.498	5.281	-	8.570	32.125
1976	22.855	3.620	11.488	2.379	5.368	-	8.570	31.426
1977	22.214	3.700	10.887	2.259	5.368[2/]	-	8.570	30.785

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kWh produced correspond to 0.53 t.c.e. (efficiency of 23.1 %).

2/ Derived from Annuario Estadistico 1977 OLADE.

3/ Calorific value: $3x10^6$ Kcal/m^3.

Table III.2. Colombia: crude petroleum balance and refinery capacity

(Millions of metric tons of coal equivalent)

	Total petroleum production (including off-shore)	Off-shore petroleum production	Import	Export	Addition to stocks	Apparent supply	Refinery capacity
1950	4.711	-	-	3.910	N.A.	0.801	1.500
1960	7.584	-	-	4.353	N.A.	3.231	3.650
1970	11.327	-	-	4.203	N.A.	7.124	6.700
1973	9.493	-	-	1.340	N.A.	8.153	8.100
1974	8.686	-	-	0.068	N.A.	8.618	8.670
1975	8.102	-	-	-	N.A.	8.102	8.670
1976	7.553	-	0.930	-	N.A.	8.483	8.670
1977	7.150	-	-	-	N.A.	-	-

Source: Data derived from U.N. statistics, primarily Ref. [7].

N.A. = not available.

Table III.3. Colombia: energy trade
(Millions of metric tons of coal equivalent[1/])

	1973	1974	1975	1976
Crude petroleum				
Import	-	-	-	1.367
Export	1.970	0.100	-	-
Energy balance (Exp.-Imp.)	+1.970	+0.100	-	-1.367
Energy petroleum products				
Import	0.013	0.043	0.335	0.502
Export	2.363	2.258	1.970	1.986
Energy balance (Exp.-Imp.)	2.350	2.215	1.635	1.484
Natural gas				
Import	-	-	-	-
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-	-	-	-
Solid fuel				
Import	0.001	-	-	-
Export	0.029	0.040	0.036	0.004
Energy balance	+0.028	+0.040	+0.036	+0.004
TOTAL				
Import	0.014	0.043	0.335	1.869
Export	4.362	2.398	2.006	1.990
Energy balance (Exp.-Imp.)	+4.348	+2.355	+1.671	+0.121

Source: Data derived from U.N. statistics, primarily Ref. [7], except for energy petroleum products obtained as difference.

1/ 1 ton petroleum = 1.47 tons coal equivalent.

Table III.4. Colombia: production, trade and consumption of electricity
(Thousand millions of kilowatt hours)

	Total production	Imports	Exports	Total consumption	Per capita consumption (in kWh)	Per capita installed capacity (in kW)
1973	12.596	-	-	12.596	564	0.141
1974	13.203	-	-	13.203	575	0.153
1975	14.485	-	-	14.485	613	0.154
1976	15.343	-	-	15.343	631	0.158

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table III.5. Colombia: production of electricity by type
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	1.147	0.422	0.725	-	0.112	N.A.	N.A.	1.035	N.A.	N.A.
1960	3.750	1.163	2.585	-	0.645	0.542	0.103	3.105	0.621	2.484
1970	8.750	2.316	6.434	-	0.912	0.400	0.512	7.838	1.916	5.922
1973	12.596	4.503	8.093	-	1.755	1.455	0.300	10.841	3.048	7.793
1974	13.203	4.188	9.015	-	1.580	1.300	0.280	11.623	2.838	8.735
1975	14.485	4.570	9.915	-	1.700	1.400	0.300	12.785	3.170	9.615
1976	15.343	5.263	10.080	-	1.750	1.450	0.300	13.593	3.813	9.780

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table III.6. Colombia: installed capacity of power plants
(Thousands of kilowatts)

	Total production				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	N.A.	N.A.	N.A.	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1960	911	406	505	-	241	196	45	670	210	460
1970	2700	904	1796	-	623	292	331	2077	612	1465
1973	3142	1194	1948	-	350	250	70	2792	914	1878
1974	3519	1196	2323	-	350	250	70	3169	916	2253
1975	3650	1327	2323	-	350	250	70	3300	1047	2253
1976	3850	1430	2420	-	350	250	70	3500	1150	2350

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table III.7. Colombia: utilization of installed electric generating capacity
(Kilowatt hours produced per kilowatt)

	Total utilization				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	N.A.	N.A.	N.A.	-	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1960	4116	2865	5123	-	2676	2765	2289	4634	2957	5400
1970	3241	2562	3582	-	1464	1370	1547	3774	3131	4042
1973	4009	3771	4155	-	5014	5196	4286	3883	3335	4150
1974	3752	3502	3881	-	4514	4643	4000	3668	3153	3877
1975	3968	3444	4268	-	4857	5000	4286	3874	3028	4268
1976	3985	3680	4165	-	5000	5179	4286	3884	3316	4162

<u>Source</u>: Data derived from U.N. statistics, primarily Ref. [7].

Table III.8. Colombia: energy consumption
(Millions of metric tons of coal equivalent)

	Total commercial energy consumption		Solid fuel	Liquid fuel	Gas	Primary[1] hydro and geo electricity	Nuclear energy	Fuelwood [3]	Total energy consumption	
	Aggregate	Per capita (t.c.e.)							Aggregate	Per capita (t.c.e.)
1950	N.A.	N.A.	1.010	2.243	N.A.	0.385	-	N.A.	N.A.	N.A.
1960	8.623	0.559	2.600	4.108	0.538	1.377	-	N.A.	N.A.	N.A.
1970	15.431	0.731	2.747	7.310	1.950	3.424	-	N.A.	N.A.	N.A.
1973	18.201	0.813	3.019	8.319	2.556	4.307	-	8.751	26.772	1.197
1974	19.239	0.838	3.225	8.738	2.475	4.801	-	8.571	27.810	1.211
1975	19.896	0.841	3.411	8.706	2.498	5.281	-	8.571	28.476	1.204
1976	20.785	0.855	3.616	9.422	2.379	5.368	-	8.571	29.356	1.207
1977						5.365[2]	-	[illegible]		

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kWh produced correspond to 0.53 t.c.e. (efficiency of 23.[illegible] %).

2/ Derived from Annuario Estadistico 1977 OLADE.

3/ Calorific value: 3×10^6 Kcal/m^3.

Chapter IV. Subregion 4: Central America and Panama

1. Present energy situation

Production of primary energy

The Central American countries have always been largely dependent on external sources of energy. Domestic production has always been confined to the production of hydroelectricity or non-commercial energy and, in total, it has never satisfied the energy demand of the subregion. Data on energy production over the period 1973-76 are reported globally in Table IV.1, whence it can be seen that the production of energy increased by some 15 per cent over this period.

40 per cent of this increase was due to increased production in the hydroelectric sector. The remaining 60 per cent was due to the increase in non-commercial sources of energy (fuelwood, bagasse, etc.). However, the expansion of fuelwood use was especially significant: 35 per cent over a three-year period, with an annual growth rate of more than 10 per cent.

The increase in the hydroelectric sector in the period 1973-76 was particularly high in some countries such as Panama (Canal Zone) (69 per cent) and El Salvador (62.5 per cent). In 1976, 68 per cent of the global hydroelectric production was attributable to only three countries: Costa Rica (37 per cent), El Salvador (18 per cent) and Honduras (13 per cent). Despite very limited dimensions, Panama (Canal Zone) produced nine per cent of the total hydroelectric production. The rest was shared between Nicaragua (11 per cent), Guatemala (9 per cent) and Panama (3 per cent). Belize has no hydropower plants.

As for the production of other forms of commercial energy, the situation has not been very positive up to now. None of the countries in the subregion is an oil producer, except for Guatemala which started production in 1976 (some six per cent of the commercial energy produced in the country). In 1977 this production had more than doubled: however, the share of commercial and non-commercial energy production covered by oil was always very little (less than one per cent).

None of the countries considered produces coal. The production of electricity by means of nuclear power-plants is confined to the Panama Canal Zone. The production of non-commercial energy has been always much higher than that of commercial energy, the ratio being about 5 : 1 in 1976. In Table IV.1. data about non-commercial energy production are also shown. Production of fuelwood, charcoal, bagasse and other vegetable-origin fuel are included in these data. However, owing to the difficulty of collecting data on these sources of energy, the figures must be regarded as indicative rather than determined values. Reference [1] gives lower figures, but in the same order of magnitude. Some 78 per cent of the non-commercial energy produced in the subregion was derived from fuelwood or charcoal, and it was utilized by the local population to meet their basic energy needs. The remainder came from bagasse waste, and the recent expansion of sugar production has brought about an increase in the production of bagasse.

Trade in energy and production of secondary energy

Owing to the limited production of primary energy in the countries of the subregion, about 90 per cent (1976 datum) of the commercial energy needed was imported from abroad. Energy imports over the period 1973-76 showed some fluctuations: between 1975 and 1976 imports dropped by more than 15 per cent (2.7 x 10^6 t.c.e.) with a corresponding drop in exports (50 per cent i.e. 10^6 t.c.e.). These figures can be derived from Table IV.2. where exports-imports data are reported for the period 1973-76. In Tables IV.3. and IV.4. trade in energy is reported by country, for 1973 and 1976 respectively.

From the data presented it can be seen that about 55 per cent of total energy imports was crude petroleum, the rest being almost entirely made up of other oil-derivatives. Except for Belize and Panama (Canal Zone) (which have no refineries to process crude oil) all the other countries in the subregion imported crude oil over the period considered. Depending in the refinery capacity available, the ratio of crude oil to refined petroleum products in total hydrocarbon imports varied from country to country. The refinery capacity of each country is reported for the period 1973-76 in Table IV.5.

In some countries, such as Honduras, Nicaragua and Panama, refinery capacity exceeded domestic demand for refined products. Consequently, these countries exported part of their refined oil. However, the volume of exports decreased between 1973 and 1976 owing to increased domestic demand which was not matched by a similar increase in refinery capacity. Only Panama made an appreciable effort in this sector and doubled its refinery capacity between 1974 and 1976. Other countries such as Guatemala and Costa Rica imported a large share of their hydrocarbons in the form of refined products (37 and 59 per cent respectively). El Salvador was self sufficient, while Belize and Panama (Canal Zone) imported all their oil requirements in the form of refined petroleum.

Natural gas is not imported into the countries of the subregion because of the costs and technological problems associated with the transportation of gas. As for coal, the trade situation is not positive, since only Panama imported coal between 1973 and 1975. However, these imports were very limited (less than 0.2 per cent of the total national energy imports) and stopped completely in 1976.

Production of electricity

Data concerning production and trade of electric energy over the period 1973-76 are reported in Table IV.6. In Table IV.7. the production of and trade in electricity are given by country for the years 1973 and 1976. Overall increment in production over that period was some 22 per cent, with an annual growth rate of 6.9 per cent. The corresponding annual increment in overall installed power-plant capacity increased by only 4.2 per cent. As a consequence, the average power plant utilization increased from 3,560 to 3,850 kWh/kW. These figures can be derived from Tables IV.6., IV.7., IV.8., IV.12., IV.13. and IV.14., in which data are given as to the global installed capacity of power plants for the period 1973-6 and its breakdown, by country, for the years 1973 and 1976.

Data given in Table IV.9. show that the oil crisis at the beginning of '70s provided an impetus for these countries to make increasing use of their hydrological reserves. The production of electricity by means of hydropower increased by more than 36 per cent in three years (1973-76), the corresponding figure for thermal generation being only 12 per cent over the same period. The trend towards the use of hydropower stations to cover the basic load of the electric energy consumption curve is reflected in the increased utilization of these types of plants: 21 per cent between 1973 and 1976 (in 1976 it was 4,953 kWh/kW). On the other hand the utilization of thermal power stations remained approximately constant (3,200 kWh/kW).

In 1976, the share of electricity produced by hydropower in the subregion was 48 per cent. In some countries, this share was much larger: in Costa Rica the figure was 88 per cent of the total electricity produced, in Honduras 83 per cent, and in El Salvador 60 per cent. Of particular interest is the exploitation of geothermal energy for electricity production in El Salvador. In 1977, the 60 MW power plants of Ahuachapan supplied some 32 per cent of the electricity produced in that country. In other countries thermal generation was the main source: Belize 100 per cent, Panama 93 per cent, and Guatemala 73 per cent (1976 datum). The utilization of nuclear energy is very limited. The only nuclear power plant in the region is located in the canal zone in Panama and it produced only 0.2 per cent of the total electricity produced in Central America.

Despite the more pronounced increase in the production of hydroelectricity as against thermal power, the rate at which installed capacity increased for both types of plants was the same (12-13 per cent between 1973 and 1976).

Self-suppliers of electricity utilized thermal generation to a greater degree: as usual, the self-suppliers were refineries and industrial plants with access to cheap fuel or with stand-by electricity generators. As a consequence, the largest share of energy produced by self-suppliers was in those countries with large refinery capacities (in relation to the size of the country), such as Guatemala (18 per cent of the national energy production), Panama (11 per cent) or Nicaragua (10 per cent).

Trade in electricity within the subregion was very limited: less than 0.7 per cent of the total production. No energy was exported to countries outside the subregion. Trade in electricity within the subregion will be increased on the basis of studies on electricity linkages which have been already started. /The average efficiency of the thermal power planst was assumed to be 26 per cent (i.e. 3300 Kcal/kWh) in 1976./

Consumption of energy

Consumption of commercial energy in the Central American countries increased by 12.6 per cent over the period 1973-76, with an annual growth rate of 4 per cent. If non-commercial energy is included, these figures drop to 11.5 and 3.7 per cent, respectively. Tables IV.15., IV.16. and IV.17. show the global energy consumption and its breakdown by country for the period 1973-76.

Some 45 per cent of the total primary energy consumption comprised non-commercial energy. The reason for this predominance of non-commercial resources lies in the economy of these countries, and in the lack of other national energy resources. Among the commercial forms of energy, liquid fuels represent the largest share, some 80 per cent of the total. Since none of the countries considered produces oil, all oil has to be imported from abroad. The consumption of liquid fuels did not increase appreciably over the period considered: 8.1 per cent in three years at an annual growth rate of 2.6 per cent.

In countries such as Panama, Panama (Canal Zone), and, to a certain extent, Guatemala, most of the oil imported is not used for domestic consumption. It is used to fuel ships which pass through the Panama Canal. In Panama this share was about 44 per cent, or 1.35 times greater than the real national consumption of energy (1976 datum). In the Panama Canal Zone this feature was even more pronounced; oil for fueling bunkers accounted for some 90 per cent of the total energy imports, i.e. 7.7 times greater than the domestic consumption of energy.

Per capita energy consumption in the Panama Canal Zone was some 30 times greater than the average consumption of the other countries. This fact can be explained by the high concentration of industrial equipment needed to operate the canal in a very small area.

The only other form of commercial energy at present utilized in the area is hydroelectric energy. This sector underwent an appreciable development between 1973 and 1976, and productivity (and consequently utilization) increased by more than 36 per cent, and the annual growth rate was 11 per cent. This development was particularly important for countries such as Panama whose capacity increased more than four-fold (4.2) in only three years (however, hydroelectricity production in Panama was always the lowest in Central America). El Salvador increased production in this sector by 62 per cent, while in Costa Rica the increase was 28 per cent. Costa Rica, however, produced about 38 per cent of the hydroelectricity produced in the whole subregion in 1976. The efforts made by this country in this sector are reflected in the fact that, in 1976, 88 per cent of the domestic demand for electricity was met by this renewable energy resource.

As for the energy consumed, 37 per cent was utilized in the residential and commercial sector, 32 per cent in the agro-industrial sector, and 30 per cent in the transport sector. However, owing to high losses and inefficiencies, actual utilization was totally different: the residential and transport sectors accounted for 16 per cent each, while the agro-industrial sector consumed the remainder of the overall energy utilized.

2. National energy resources

Despite the pronounced oil dependence of Central America on external oil sources, few efforts have been concentrated on exploratory activities in this sector. Only recently have oil discoveries in Mexico induced private and national companies to start exploration. Initial results would seem positive - at least for some of the countries - but many other investigations are still necessary to determine the real amount of reserves. The situation in respect of both gas and coal reserves is negative.

The best prospects are offered by hydroelectric and geothermal resources. Some of the countries already derive a large proportion of their electricity production from hydropower, and prospects still appear good. Furthermore, owing to volcanic activity throughout the region, good possibilities open up in the geothermal sector. Following the oil crisis, many governments improved their geothermal energy programmes and the concrete results can already be seen in the power plants which are, or will be, in operation.

Petroleum reserves

The recent oil discoveries in Mexico opened up prospects of other important discoveries in Central America. In many Central American countries the geological formations are very similar to the oil-rich formations of the Chiapas-Tabasco area in Mexico.

Furthermore, in the northern part of Guatemala, the country closest to Mexico, oil was discovered and production started in 1975 at the rate of 140 barrels per day. Production was more than doubled in 1977 and, in the short term, some 5,000 barrels per day are envisaged. Another indication of the possible oil reserves is the number of concessions that have been granted for exploratory purposes. Some 40 per cent of the total surface of the region would seem to have been opened up to intensive exploration. Honduras and Guatemala, in particular, would seem to have the best prospects.

Gas reserves

At present, no data are available on gas reserves in Central America. The limited exploratory activity in the subregion failed to produce any discoveries, not even in the oil sector. However, the prospects raised by the recent Mexican discoveries, and the new oil-prospecting activities will also encourage exploration in this sector.

Coal reserves

Some of the countries of the subregion would seem to have coal reserves of some significance. However, as for the oil and gas sector, the lack of adequate exploratory activities has not permitted an evaluation of possible reserves. Only recently did Honduras, which is assumed to have the richest coal reserves in the region, decide to evaluate its national coal reserves.

Hydroelectric reserves

The energy crisis of the past years induced many of the governments in Central America to re-evaluate the possibility of exploiting their hydrological reserves to a greater degree. This trend has become apparent in recent years, and many efforts have been devoted to this sector. Reserves have been evaluated at varying levels: at the first level, consideration was only given on a general plane to theoretically exploitable potentials, whereafter more detailed studies were undertaken in respect of specific projects. On the basis of this latter evaluation, the hydroelectric potential of the region is distributed as follows (Ref. [1]):

	Megawatts
Guatemala	9,900
El Salvador	950
Honduras	2,800
Nicaragua	2,950
Costa Rica	8,900
Panama	1,600
Total	27,100

(In this list, the Belize potential is included in that of Honduras, while that of Panama includes the canal zone.)

Since no economical evaluation has been made of these projects, the individual shares in the hydrological potential as reported should not be considered definite as they may not be economically exploitable. In any event, according to the figures cited, some 69 per cent of the reserves are concentrated in only two countries, Guatemala and Costa Rica (Costa Rica is already exploiting hydropower to a very high degree). The remaining 30 per cent is distributed unevenly among the other countries: Honduras and Nicaragua account for 21 per cent of the total reserves.

Other figures are presented in reference [13]. The total hydrological reserves are estimated to be 22,060 MW. This figure differs by some 20 per cent from the other figure presented. The potential is said to be distributed as follows:

	Megawatts
Guatemala	6,400
El Salvador	630
Honduras	5,130
Nicaragua	3,270
Costa Rica	3,100
Panama	3,530
Total	22,060

Geothermal reserves

Particular interest has been shown by the Central American countries in the exploitation of geothermal resources. The whole area has a very intense geothermal activity which at present is scarcely utilized.

The most interesting utilization of geothermal reserves has been carried out in El Salvador. In 1977, some 32 per cent of the total electric energy produced in the country came from geothermal energy. In the Ahuachapan field, where the geothermal power plant of El Salvador is located, exploratory activity has revealed other possible sources which will be exploited in the near future. By 1984, two other power plants are scheduled to be built. Advanced studies have also been carried out in Nicaragua. In the area of Momotombo, a 35 MW power plant will be started up by the end of 1980. For budgetary reasons, the country's total efforts are concentrated solely on this field, which is expected to yield some 100 MW.

In Costa Rica, initial explorations have been carried out. Good prospects were revealed for the exploitation of geothermal energy near the volcano Miravalles. The second stage of the investigation, involving the technical and economical aspects of exploitation, has already started. In the near future, Costa Rica should also be able to produce electricity by means of geothermal energy.

In the remaining countries exploratory activities are only in the initial stages: they are more advanced in Guatemala, less so in Panama and Honduras.

From the geothermal point of view, Nicaragua and Guatemala have the best prospects, followed by El Salvador, Costa Rica, Honduras and Panama. In terms of probable exploitable potential, the whole region should have some 8,800 MW of which 1,600 are very probable. The use of geothermal power could reduce the dependence on oil, at least in the electricity generation sector.

Uranium reserves

No data are available on the uranium reserves of Central America.

Non-commercial energy reserves

In this subregion, the non-commercial resources of energy also come from the sun and agriculture. In geographical terms, the region is sufficiently well located for solar energy exploitation. As usual, the constraints are technical. However, specific technologies for local use in the residential and agricultural sector are being developed in the local research institutes.

More interesting is the situation in respect of the utilization of agricultural waste for energy production. The main crop in the region is sugar cane: the residue (bagasse) could be for direct combustion as fuel, and one of the by-products (molasses) for the production of alcohol.

3. National energy policies

Historically, all the governments of Central America have always had to face a dual problem: the scarcity of local commerical energy production on the one hand, and the need for energy to develop their economies on the other. Depending on the local evolution of the national economies, some countries have tried to meet domestic demand for energy through the use of non-commercial forms of energy, generally of vegetable origin or from the processing of agricultural products. Except for the last few years this exploitation has not been organized on an industrial scale, but has remained confined to local initiative. Non-commercial energy has been mostly used to meet the basic energy needs of part of the population. Countries with different economies have tried to overcome the problem partially by developing an economy based on transforming a share of the primary energy, some of which could then be exported (e.g. petroleum refinery).

In recent years, increased oil prices have obliged many governments to revise their economy strategies. On the one hand, attempts have been made to limit or contain oil imports and on the other, to develop and organize the use of local alternative forms of energy.

The practical consequence has been a different trend in the production, consumption and use of energy that can be summarized as follows:

- A number of studies and investigations on the present energy situation and its future prospects. These studies have been partially carried out by some supranational institutions which elaborated two different energy programmes for Central America: the first in 1973, and the second in 1977.
- An appreciable increase in hydroelectricity production over the past few years. This trend is confirmed by data already reported and by the exploration and development programme in this sector.
- Introduction of geothermal energy in the electric generation sector. Countries, such as El Salvador and Nicaragua, are already very advanced in this field, and almost all the Central American countries are effectively investigating their national geothermal resources. Since initial results were very positive, it seems likely that the subsequent development programmes will be maintained.
- Increased efforts dedicated to oil discoveries in the region. Since, at present, oil accounts for the largest share in energy consumption, interest in this sector is particularly great. One country has already started to produce oil.
- Utilization of agricultural waste on an industrial scale. Since the countries of the region produce large amounts of agricultural products (sugar cane is one of the most important),

the resultant waste could be effectively utilized for energy production. This sector requires new studies, experimental applications in the field followed by industrial applications, and then adequate industrial co-ordination before being launched on a large scale. Moreover, as with any new technology some time must elapse before the technologies acquire sufficient "maturity". However, studies already conducted indicate that this region shows great promise for the exploitation of these sources of energy.

4. Future energy demand

Data on energy consumption over the period 1950-75 can be extrapolated to provide an indication of possible future energy demand in the region. The Panama Canal Zone was excluded from this projection because of its very particular energy situation in comparison with the other countries of the region. However, its average annual energy consumption growth rate is much lower than the corresponding figure of the other countries in the region (only 3.5 per cent).

The average annual growth rate for commercial energy consumption and energy consumption extrapolated for the years 1985 and 2000 are presented below in some detail:

	Average annual growth rate (percentage)	Consumption in 1985 (million t.c.e.)	Consumption in 2000 (million t.c.e.)
Guatemala	6.9	3.175	8.637
Belize	9.1	0.196	0.723
El Salvador	8.7	2.648	9.256
Honduras	7.1	1.767	4.944
Nicaragua	10.3	2.923	12.746
Costa Rica	7.8	3.145	9.703
Panama	7.3	3.148	9.057
TOTAL	8-8.1	17.002	55.066

Another estimate reported in Ref.[15] quotes for 1985 an extrapolated overall consumption varying between 12 and 14 million t.c.e. according to different hypotheses of development. Reference [8] forecasts commercial energy consumption for the year 2000 and solely in respect of Costa Rica, El Salvador and Guatemala. The average annual growth rate was calculated from the data quoted therein. The results are presented below:

	Average annual growth rate (percentage)	Consumption in 2000 (million t.c.e.)
Guatemala	7.5	8.717
El Salvador	8.1	8.390
Costa Rica	6.4	6.349

These figures fit sufficiently well with the others already presented.

As for the future energy demand for electric energy, Ref. [1] gives a high global estimate for regional consumption in the year 2000. This estimate is 60,000 GWh (this corresponds to 28 million t.c.e., assuming conversion efficiency of 26 per cent).

5. Future national energy problems

The cumulative consumption of energy in the Central American countries has been estimated at some 600 million t.c.e. up to year 2000. At present, it seemsunlikely that these countries will be able to achieve self-sufficiency in the energy sector in the near future. Only important oil discoveries similar to those in Mexico in 1972 could reverse the situation.

Energy supply problems can be faced on the basis of three approaches:

- Limiting domestic consumption, avoiding, whenever possible, a drop in regional economical growth, and eliminating inefficiencies and losses in the system;
- Promoting the development of local energy resources, above all when coupled with existing infrastructures (e.g. agriculture); and
- Importing primary energy from foreign countries.

However, in particular fields of the energy sector, the region has already shown its potential self-sufficiency. Thanks to the abundance of hydro and geothermal resources in certain countries, electric energy production could be met entirely by these forms of energy. It has been calculated that the region's hydroelectric resource would meet the demand for electricity even after the year 2000.

Table IV.1. Central America and Panama: production of primary energy
(Millions of metric tons of coal equivalent)

	1950	1960	1970	1973	1974	1975	1976	1977
Guatemala								
Hydro 1/	0.019	0.058	0.158	0.150	0.154	0.150	0.161	N.A.
Liquid fuel	-	-	-	-	-	-	0.010	0.022
Non-commercial energy	N.A.	N.A.	N.A.	1.928	2.194	2.194	2.194	N.A.
Total	N.A.	N.A.	N.A.	2.078	2.348	2.344	2.365	N.A.
Belize								
Hydro 1/	-	-	-	-	-	-	-	-
Non-commercial energy	N.A.	N.A.	N.A.	0.028	0.029	0.030	0.030	N.A.
Total	N.A.	N.A.	N.A.	0.028	0.029	0.030	0.030	N.A.
El Salvador								
Hydro 1/	0.019	0.111	0.223	0.208	0.246	0.227	0.338	N.A.
Non-commercial energy	N.A.	N.A.	N.A.	0.984	0.984	1.363	1.363	N.A.
Total	N.A.	N.A.	N.A.	1.192	1.230	1.590	1.701	N.A.
Honduras								
Hydro 1/	0.004	0.008	0.092	0.169	0.192	0.215	0.235	N.A.
Non-commercial energy	N.A.	N.A.	N.A.	1.328	1.286	1.286	1.286	N.A.
Total	N.A.	N.A.	N.A.	1.497	1.478	1.501	1.521	N.A.
Nicaragua								
Hydro 1/	0.008	0.004	0.150	0.150	0.173	0.177	0.192	N.A.
Non-commercial energy	N.A.	N.A.	N.A.	0.857	0.900	0.915	0.915	N.A.
Total	N.A.	N.A.	N.A.	1.007	1.073	1.092	1.107	N.A.
Costa Rica								
Hydro 1/	0.084	0.184	0.446	0.538	0.592	0.615	0.688	N.A.
Non-commercial energy	N.A.	N.A.	N.A.	0.913	0.914	0.940	0.940	N.A.
Total	N.A.	N.A.	N.A.	1.451	1.506	1.555	1.628	N.A.
Panama								
Hydro 1/	0.004	0.008	0.038	0.042	0.050	0.046	0.054	N.A.
Non-commercial energy	N.A.	N.A.	N.A.	0.600	0.600	0.600	0.600	N.A.
Total	N.A.	N.A.	N.A.	0.642	0.650	0.646	0.654	N.A.
Panama (canal zone)								
Hydro 1/	0.119	0.115	0.146	0.100	0.135	0.107	0.169	N.A.
Non-commercial energy	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Total	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
TOTAL								
Hydro 1/	0.257	0.488	1.253	1.357	1.542	1.537	1.837	N.A.
Liquid fuel	-	-	-	-	-	-	0.010	0.022
Non-commercial energy	N.A.	N.A.	N.A.	6.638	6.907	7.328	7.328	N.A.
Total 2/	N.A.	N.A.	N.A.	7.995	8.449	8.865	9.175	N.A.

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kWh produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Not including non-commercial energy production in Panama canal zone.

N.A. = not available.

Table IV.2. Central America and Panama: energy trade
(Millions of metric tons of coal equivalent[1/])

	1973	1974	1975	1976
Crude petroleum				
Import	10.249	9.967	11.017	8.314
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-10.249	-9.967	-11.017	-8.314
Energy petroleum products				
Import	7.106	6.764	6.750	6.763
Export	1.402	1.939	2.137	1.071
Energy balance (Exp.-Imp.)	-5.704	-4.825	-4.613	-5.692
Natural gas				
Import	-	-	-	-
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-	-	-	-
Solid fuel				
Import	0.013	0.005	0.001	-
Export	-	-	-	-
Energy balance (Exp.-Imp.)	-0.013	-0.005	-0.001	-
TOTAL				
Import	17.368	16.736	17.768	15.077
Export	1.402	1.939	2.137	1.071
Energy balance (Exp.-Imp.)	-15.966	-14.797	-15.631	-14.006

Source: Data derived from U.N. statistics, primarily Ref. [7], except for energy petroleum products obtained as difference.

1/ 1 ton petroleum = 1.47 tons coal equivalent.

Table IV.3. Central America and Panama: energy trade by country (1973)
(Millions of metric tons of coal equivalent[1/])

	Guatemala	Belize	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Panama (canal zone)	TOTAL
Crude petroleum									
Import	1.382	-	0.904	1.001	0.804	0.657	5.501	-	10.249
Export	-	-	-	-	-	-	-	-	-
Energy balance (Exp.-Imp.)	-1.382	-	-0.904	-1.001	-0.804	-0.657	-5.501	-	-10.249
Energy petroleum products									
Import	0.068	0.078	0.019	0.070	0.093	0.277	0.032	6.469	7.106
Export	0.003	-	0.015	0.334	0.007	-	0.857	0.186	1.402
Energy balance (Exp.-Imp.)	-0.065	-0.078	-0.004	+0.264	-0.086	-0.277	+0.825	-6.283	-5.704
Solid fuel									
Import	-	-	-	-	-	-	0.013	-	0.013
Export	-	-	-	-	-	-	-	-	-
Energy balance (Exp.-Imp.)	-	-	-	-	-	-	-0.013	-	-0.013
TOTAL									
Import	1.450	0.078	0.923	1.071	0.897	0.934	5.546	6.469	17.368
Export	0.003	-	0.015	0.334	0.007	-	0.857	0.186	1.402
Energy balance (Exp.-Imp.)	-1.447	-0.078	-0.908	-0.737	-0.890	-0.934	-4.689	-6.283	-15.966

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ 1 ton petroleum = 1.47 t.c.e.

Table IV.4. Central America and Panama: energy trade by country (1976)
(Millions of metric tons of coal equivalent[1/])

	Guatemala	Belize	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Panama (canal zone)	TOTAL
Crude petroleum									
Import	1.091	-	1.065	0.583	1.065	0.388	4.122	-	8.314
Export	-	-	-	-	-	-	-	-	-
Energy balance (Exp.-Imp.)	-1.091	-	-1.065	-0.583	-1.065	-0.388	-4.122	-	-8.314
Energy petroleum products									
Import	0.647	0.098	0.012	0.033	0.094	0.564	0.571	4.744	6.763
Export	-	-	0.012	0.027	0.006	-	0.975	0.051	1.071
Energy balance (Exp.-Imp.)	-0.647	-0.098	0.000	-0.006	-0.088	-0.564	+0.404	-4.693	-6.692
TOTAL									
Import	1.738	0.098	1.077	0.616	1.159	0.952	4.693	4.744	15.077
Export	-	-	0.012	0.027	0.006	-	0.975	0.051	1.071
Energy balance (Exp.-Imp.)	-1.738	-0.098	-1.065	-0.589	-1.153	-0.952	-3.718	-4.693	-14.006

Source: Data derived from U.N. statistics, primarily Ref. [7], except for energy petroleum products obtained as difference.

1/ 1 ton petroleum = 1.47 t.c.e.

Table IV.5. Central America and Panama: refinery capacity
(Millions of metric tons of coal equivalent)

	Guatemala	Belize	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Panama (canal zone)	TOTAL
1950	-	-	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	-	-	-
1970	1.250	-	0.650	0.700	0.650	0.400	4.000	-	7.65
1973	1.250	-	0.650	0.700	0.650	0.470	4.000	-	7.720
1974	1.250	-	0.650	0.700	0.650	0.470	5.000	-	8.720
1975	1.250	-	0.750	0.700	0.750	0.470	5.000	-	8.920
1976	1.250	-	0.750	0.700	0.750	0.470	10.000	-	13.920

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table IV.6. Central America and Panama: production, trade and consumption of electricity
(Thousand millions of kilowatt hours)

	Production	Imports	Exports	Aggregate consumption	Per capita consumption (kWh)	Per capita installed capacity (kW)
1950	0.807	0.001	0.001	0.807	89 (61[1])	0.027 (0.018[1])
1960	1.569	-	-	1.569	129 (107[1])	0.041 (0.036[1])
1970	4.347	0.117	0.117	4.347	269 (234[1])	0.078 (0.069[1])
1973	6.486	0.106	0.106	6.486	366 (325[1])	0.103 (0.093[1])
1974	7.025	0.064	0.064	7.025	384 (365[1])	0.104
1975	7.392	0.047	0.047	7.392	390 (354[1])	0.104
1976	7.936	0.055	0.055	7.936	405 (373[1])	0.105 (0.096[1])

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Canal zone excluded.

Table IV.7. Central America and Panama: production, trade and consumption of electricity by country (1973)
(Thousand millions of kilowatt hours)

	Production	Imports	Exports	Aggregate consumption	Per capita consumption (in kWh)	Per capita installed capacity (in kW)
Guatemala	1.020	-	-	1.020	178	
Belize	0.028	-	-	0.028	242	0.050
El Salvador	0.912	-	-	0.912	242	0.068
Honduras	0.441	-	-	0.441	170	0.052
Nicaragua	0.714	-	-	0.714	354	0.131
Costa Rica	1.346	-	-	1.346	719	0.193
Panama	1.359	0.019	0.087	1.291	822	0.201
Panama (canal zone)	0.666	0.087	0.019	0.734	17,902	4.488
TOTAL	6.486	0.106	0.106	6.486	366 1/ 325 2/	0.103 1/ 0.093 2/

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Weighted average.

2/ Weighted average, canal zone excluded.

Table IV.8. Central America and Panama: production, trade and consumption of electricity by country (1976)
(Thousand millions of kilowatt hours)

	Production	Imports	Exports	Aggregate consumption	Per capita consumption (in kWh)	Per capita installed capacity (in kW)
Guatemala	1.250	-	-	1.250	200	0.053
Belize	0.043	-	-	0.043	299	0.083
El Salvador	1.199	-	-	1.199	291	0.084
Honduras	0.590	-	0.021	0.569	201	0.059
Nicaragua	1.040	0.021	-	1.061	475	0.121
Costa Rica	1.646	-	-	1.646	791	0.195
Panama	1.508	0.022	0.012	1.518	883	0.201
Panama (canal zone)	0.660	0.012	0.022	0.650	16,250	4.525
TOTAL	7.936	0.055	0.055	7.936	405 1/ 373 2/	0.105 1/ 0.096 2/

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Weighted average.

2/ Weighted average, canal zone excluded.

Table IV.9. Central America and Panama: production of electricity by type
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public			
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro	Nuclear
1950	0.807	0.266	0.541	-	0.101	0.074	0.027	0.706	0.192	0.514	-
1960	1.756	0.717	1.039	-	0.195	0.178	0.017	1.561	0.539	1.022	-
1970	4.974	2.301	2.628	0.045	0.477	0.389	0.088	4.497	1.912	2.540	0.045
1973	6.490	3.614	2.830	0.046	0.528	0.485	0.043	5.962	3.129	2.787	0.046
1974	7.025	3.760	3.239	0.026	0.571	0.540	0.031	6.454	3.220	3.208	0.026
1975	7.392	4.140	3.227	0.025	0.582	0.521	0.061	6.810	3.619	3.166	0.025
1976	7.936	4.057	3.859	0.020	0.656	0.588	0.068	7.280	3.469	3.791	0.020

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table IV.10. Central America and Panama: production of electricity by type and by country (1973)
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public			
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro	Nuclear
Guatemala	1.020	0.702	0.318	-	0.162	0.162	-	0.858	0.540	0.318	-
Belize	0.032	0.032	-	-	-	-	-	0.032	0.032	-	-
El Salvador	0.912	0.472	0.440	-	0.040	0.040	-	0.872	0.432	0.440	-
Honduras	0.441	0.082	0.359	-	0.050	0.050	-	0.391	0.032	0.359	-
Nicaragua	0.714	0.394	0.320	-	0.096	0.070	0.026	0.618	0.324	0.294	-
Costa Rica	1.346	0.209	1.137	-	0.059	0.042	0.017	1.287	0.167	1.120	-
Panama	1.359	1.268	0.091	-	0.121	0.121	-	1.238	1.147	0.091	-
Panama (canal zone)	0.666	0.455	0.165	0.046	-	-	-	0.666	0.455	0.165	0.046
TOTAL	6.490	3.614	2.830	0.046	0.528	0.485	0.043	5.962	3.129	2.787	0.046

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table IV.11. Central America and Panama: production of electricity by type and by country (1976)
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public			
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro	Nuclear
Guatemala	1.250	0.910	0.340	-	0.230	0.195	0.035	1.020	0.715	0.305	-
Belize	0.043	0.043	-	-	-	-	-	0.043	0.043	-	-
El Salvador	1.199	0.483	0.716	-	0.053	0.053	-	1.146	0.430	0.716	-
Honduras	0.590	0.097	0.493	-	0.047	0.047	-	0.543	0.050	0.493	-
Nicaragua	1.040	0.635	0.405	-	0.105	0.090	0.015	0.935	0.545	0.390	-
Costa Rica	1.646	0.190	1.456	-	0.056	0.038	0.018	1.590	0.152	1.438	-
Panama	1.508	1.398	0.110	-	0.165	0.165	-	1.343	1.233	0.110	-
Panama (canal zone)	0.660	0.301	0.339	0.020	-	-	-	0.660	0.301	0.339	0.020
TOTAL	7.936	4.057	3.859	0.020	0.656	0.588	0.068	7.280	3.469	3.791	0.020

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table IV.12. Central America and Panama: installed capacity of power plants
(Thousands of kilowatt hours)

	Total capacity				Industrial			Public			
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro	Nuclear
1950	246	116	130	-	39	30	9	207	86	121	-
1960	507	279	228	-	82	67	15	425	212	213	-
1970	1257	712	535	10	162	146	16	1095	566	519	10
1973	1823	1121	692	10	227	208	19	1596	913	673	10
1974	1920	1217	693	10	244	225	19	1676	992	674	10
1975	1975	1228	737	10	283	247	36	1692	981	701	10
1976	2061	1272	779	10	293	256	37	1768	1016	742	10

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table IV.13. Central America and Panama: installed capacity of power plants by country (1973)
(Thousands of kilowatts)

	Total capacity				Industrial			Public			
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro	Nuclear
Guatemala	285	183	102	-	60	60	-	225	123	102	-
Belize	9	9	-	-	-	-	-	9	9	-	-
El Salvador	269	160	109	-	24	23	1	245	137	108	-
Honduras	134	65	69	-	13	13	-	121	52	69	-
Nicaragua	264	157	107	-	47	40	7	217	117	100	-
Costa Rica	362	119	243	-	37	26	11	325	93	232	-
Panama	316	301	15	-	46	46	-	270	255	15	-
Panama (canal zone)	184	127	47	10	-	-	-	184	127	47	10
TOTAL	1823	1121	962	10	227	208	19	1596	913	673	10

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table IV.14. Central America and Panama: installed capacity of power plants by country (1976)
(Thousands of kilowatts)

	Total capacity				Industrial			Public			
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro	Nuclear
Guatemala	333	212	121	-	103	85	18	230	127	103	-
Belize	12	12	-	-	-	-	-	12	12	-	-
El Salvador	346	177	169	-	41	40	1	305	137	168	-
Honduras	168	93	75	-	13	13	-	155	80	75	-
Nicaragua	270	160	110	-	46	39	7	224	121	103	-
Costa Rica	406	167	239	-	40	29	11	366	138	228	-
Panama	345	330	15	-	50	50	-	295	280	15	-
Panama (canal zone)	181	121	50	10	-	-	-	181	121	50	10
TOTAL	2061	1272	779	10	293	256	37	1768	1016	742	10

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table IV.15. Central America and Panama: energy consumption

(Millions of metric tons of coal equivalent and tons per capita)

	Total primary commercial energy		Liquid fuel	Gas	Solid fuel	Primary 1/ hydro and geo electricity	Nuclear electricity	Fuelwood 2/	Total primary energy	
	Aggregate	Per capita							Aggregate	Per capita
1950	1.426		1.168	-	-	0.258	-	N.A.	N.A.	N.A.
1960	2.912		2.424	-	-	0.488	-	N.A.	N.A.	N.A.
1970	6.190		4.902	-	-	1.267	0.021	N.A.	N.A.	N.A.
1973	7.883	0.445	6.513	-	0.013	1.355	0.022	6.638	14.521	0.820
1974	8.104	0.442	6.555	-	0.005	1.537	0.012	6.907	15.011	0.820
1975	8.562	0.452	7.008	-	0.001	1.542	0.012	7.328	15.890	0.839
1976	8.874	0.453	7.042	-	-	1.823	0.009	7.328	16.202	0.828

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Calorific value: $3x10^6$ $Kcal/m^3$.

Table IV.16. Central America and Panama: energy consumption by country (1973)
(Millions of metric tons of coal equivalent and tons per capita)

	Total primary commercial energy		Liquid fuel	Gas	Solid fuel	Primary[1/] hydro and geo electricity	Nuclear electricity	Fuelwood	Total primary energy	
	Aggregate	Per capita							Aggregate	Per capita
Guatemala	1.495	0.260	1.345	-	-	0.150	-	1.928	3.423	0.596
Belize	0.070	0.528	0.070	-	-	-	-	0.028	0.098	0.739
El Salvador	1.094	0.290	0.886	-	-	0.208	-	0.984	2.078	0.550
Honduras	0.812	0.311	0.643	-	-	0.169	-	1.328	2.140	0.821
Nicaragua	1.049	0.520	0.899	-	-	0.150	-	0.857	1.906	0.946
Costa Rica	1.432	0.764	0.894	-	-	0.538	-	0.913	2.345	1.252
Panama	1.434	0.913	1.410	-	0.013	0.011	-	0.600	2.034	1.295
Panama (canal zone)	0.497	12.115	0.366	-	-	0.109	0.022	-	0.497	12.115
TOTAL	7.883	0.445 0.418[2/]	6.513	-	0.013	1.335	0.022	6.638	14.521	0.820 0.792[2/]

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Panama canal zone excluded.

Table IV.17. Central America and Panama: energy consumption by country (1976)
(Millions of metric tons of coal equivalent)

	Total primary commercial energy		Liquid fuel	Gas	Solid fuel	Primary[1] hydro and geo electricity	Nuclear electricity	Fuelwood[3]	Total primary energy	
	Aggregate	Per capita (t.c.e.)							Aggregate	Per capita (t.c.e.)
Guatemala	1.726	0.276	1.565	-	-	0.161	-	2.194	3.920	0.627
Belize	0.087	0.604	0.087	-	-	-	-	0.030	0.117	0.812
El Salvador	1.175	0.284	0.837	-	-	0.338	-	1.363	2.538	0.615
Honduras	0.913	0.308	0.690	-	-	0.223	-	1.286	2.199	0.743
Nicaragua	1.216	0.520	1.016	-	-	0.200	-	0.915	2.131	0.911
Costa Rica	1.525	0.757	0.837	-	-	0.688	-	0.940	2.465	1.224
Panama	1.563	0.909	1.506	-	-	0.057	-	0.600	2.163	1.259
Panama (canal zone)	0.669	16.737	0.504	-	-	0.156	0.009	-	0.669	16.737
TOTAL	8.874	0.453 0.412[2]	7.042	-	-	1.823	0.009	7.328	16.202	0.828 0.795[2]

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.47 t.c.e. (efficiency of 26 %).

2/ Panama canal zone excluded.

3/ Calorific value: $3x10^6$ Kcal/m^3.

Chapter V. Subregion 5: Mexico

1. Present energy situation

Production of primary energy

In the last 28 years, the average annual growth rate in the Mexican production of primary commercial energy has been constantly higher than the corresponding world average. In the period 1950-70, the former was about 6.5 per cent compared with a world figure of 5.2 per cent. In the more recent period of 1974-76, the Mexican energy growth rate was even higher being 11.46 per cent as against a world average of 2.4 per cent. In Table V.1. the production of the Mexican commercial and non-commercial primary energy since 1973 is reported with its breakdown. In the same table, the production of non-commercial fuel (as fuelwood) is also reported. The non-commercial energy represents only about 4 per cent of the total energy production, according to United Nations data. Other sources (CEPAL) indicates a higher value for the non-commercial energy production (indicated as vegetable fuel) of about 12 per cent for 1972. However, since the consumption of this kind of fuel remained approximately constant during the period covered by the table, it is possible to see that other forms of energy (typical of more developed countries) are replacing this traditional fuel. The increment of national oil production encouraged this trend, confining the use of fuelwood to local utilization where it is available at a very low price or as by-product of other processes (e.g. bagasse).

Between 1973 and 1976 the rapid increase in the overall national energy production was for the most part due to the increase in crude petroleum extraction (73 per cent increase in four years). In Table V.2. petroleum production and trade from 1973 to 1977 have been reported. Mexico has been an oil producer since the beginning of the century. For more than 50 years Mexican oil production has been mainly based on the Golden Lane oil field. New oil wells were discovered in 1949 and 1960 in the region of Tabasco on the south-east coast. Despite these discoveries, Mexico was still projected to be an oil importer in the 1980s.

However, the situation has changed completely in the last six years when Pemex (Petroleos Mexicanos, the national enterprise which controls most of the production and commercialization of the energy resources) made exploratory drillings in the Chiapas-Tabasco area in the south of the country, whereupon two new large oil fields were discovered near Reforma. More extended investigations revealed that the area below the Yucatan Peninsula, along the south-east Mexican coast and extending off shore more than 200 km, could be one of the richest oil regions in the world. In 1977 Pemex discovered 26 new fields, 17 oil and 9 natural gas. This produced an increase in the oil extraction of 27.7 per cent between December 1976 and December 1977, i.e. 26,000 barrels per day. This increase came mainly from the fields in the Reforma area mentioned above which in total produced an average of 647,000 barrels of crude oil daily. In order to understand the importance of this discovery, it is possible to compare this new oil field with the Pora Rica field which was for years the backbone of Mexican oil supply. Whereas, the Pora Rica field took 20 years of development to reach a production level of 150,000 barrels per day, the Reforma field has reached a production level of about 800,000 barrels per day in less than five years. This figure represents double the national production of 1967.

Natural gas production remained approximately constant in the period 1973-77 (see Table V.1.), and represented a share in the total primary energy production ranging between 17 and 25 per cent. However, following the discovery of new gas fields in the areas where oil was found, the situation will change, even though in 1977 Mexico was still importing gas from the U.S.A.

The production of solid fuels increased by about 40 per cent in the period 1973-77, but their share was always confined to about the five per cent of the primary energy production. The annual growth rate for coal extraction in those years was about 7 per cent versus the average annual world growth rate of 2.35 per cent. This increase in national coal extraction was due to:

- The rapid development of a national iron and steel industry (the processes utilize large quantities of coke to reduce iron ore);

- The increase throughout the world in the price of metallurgical coke. This increase was caused by the restriction of coke exports by U.S. coal producers.

About 70 per cent of the national production of coal and solid fuel is devoted to the metallurgical industry. The rest is used by industry, for domestic uses and power generation.

The main coal mines in Mexico are located in the northern states: Coahuilas, Oaxaca and Sonora. The coal produced in Coahuila has medium volatility (≃ 25 per cent), 23 per cent ash content and 1.2 per cent sulphur. The coals from other areas have a lower volatile, but higher ash content. Coal deposits are known to exist in other areas, but they are not considered economically exploitable.

Primary hydropower energy covered less than 10 per cent of the total energy production in 1976. It was utilized for electricity production (56 per cent of the total electrical energy production in 1974), but the increase in production was only 8.3 per cent in the period 1973-76. The new oil discoveries (and the consequent low price for oil) were only one of the reasons which has contributed to the slow development in the hydroelectric sector in Mexico (see also the next chapter). The exploitation of the geothermal potential of the country was confined to the area of Cerro Prieto where the sole geothermal power plant is located. The power of the plant is 75 MW, and it produced about 1 per cent of the country's electric energy.

Mexico at present has no nuclear reactor on line, but there is a 1,300 MW plant scheduled which would be fed with 140 tons of uranium per year.

<u>Trade in energy and secondary energy production</u>

Mexican trade in energy changed radically in the period 1973-77. The discovery of new oil fields shifted the energy export-import situation from negative to positive. From data in Table V.3. on the breakdown of Mexican trade in energy it can be seen that beginning in 1975 there was a net positive energy balance in crude oil. This largely counterbalances the negative trade balance of the other energy sectors. In 1977 Mexico remained an importer of coal and solid fuels in general as well as of refined petroleum products and natural gas. The data on natural gas in Table V.3. show an evident trend over the past few years towards limiting and reducing the export of natural gas in order to meet the national demand. Imports of gas were reduced because of the increase in national production. The same trend in the reduction of export appears in the energy petroleum products trade data of Table V.3. But since in this case national demand expanded more rapidly than national production capacity, the export-import situation was still negative in 1977, and in the last years it has shown a slight worsening trend. Refinery capacity has grown 27 per cent in the period 1973-76. In 1977 835,500 barrels of crude oil and liquid gas were processed daily in Mexican refineries, an increase of 12.7 per cent in refinery capacity over the previous year.

In 1977 Pemex exported crude oil to the United States, Canada, Israel and Spain, and liquid gas and refined products to the Netherlands, Antilles, Belize, Colombia, Ecuador, United States, Guatemala and Peru. The volume exported was in the order of 206,500 barrels per day, of which 97.8 per cent was crude oil and only 2.2 per cent was exported as refined petroleum. In 1977, the Pemex total exports were 23.4 billion pesos. These were 234 per cent more than the 1976 exports.

Electricity production

Over the last 18 years, national electricity production has had to keep pace with the rapid increase in domestic demand. This is clearly revealed by the growth pattern of the coefficient of electrification, a figure which represents the rate of total electricity consumption (in kWh) in relation to the amount of commercial fuel consumption (except for the amount delivered to the power industry). In 1961, the coefficient was 0.74 as against 1.05 in 1973: an increase of more than 40 per cent in 13 years. In Table V.4. production, trade and consumption data for electricity are shown for the period 1973-77, and production can be seen to have increased by more than 31 per cent over this period. In Table V.5., the production of electricity by type is reported for the same period, whence it can be seen that some 40 per cent of the total electricity produced was generated in hydropower stations, the remainder in thermal stations (Mexico has no nuclear power-plants).

Table V.5. also shows that, over the same period, the thermal production of electricity increased more rapidly than the production of hydroelectricity. This development can be attributed to:

- Availability of cheap oil, subsequent to the discovery of new oil fields in Mexico;
- Larger capital investments required by hydropower stations;
- Limited availability of hydrological data necessary for hydropower projects;
- Distance between the sources of hydroelectric energy and consumers.

In Table V.6. the installed capacity of power plants is reported by type. In the period 1973-77, less than 10 per cent of all electricity produced was generated in industrial installations which were partial or total self-suppliers of electric energy. Owing to the nature of their industrial processes (such as oil refineries and oil fields), these plants enjoyed access to very cheap fuel, thus making the independent production of electricity economic. However, as can be seen from Table V.5., the industrial production of electricity has decreased over the past few years, while public production has increased rapidly. This trend stems from the fact that most of the self-suppliers resorted to their own power plants in cases of emergency only, since improved public electricity generation and supply have made independent generation less advantageous. This fact can be confirmed by comparing the data in Table V.7. on the utilization of the installed power plant capacity for both industrial and public facilities.

As for the effeciency of oil-fired power plants, it stood at 26.6 per cent in 1970 and 27.8 per cent in 1974: however, large units (2+300 MW) are much more efficient, about 39 per cent.

Energy consumption

In Mexico, energy consumption expanded more rapidly than the corresponding world consumption. The average annual growth rate in the period 1950-70 was 8.04 per cent as against a world figure of 6.36 per cent. More recently, between 1974 and 1976, the Mexican annual increase was 3.64 per cent compared with a world average value of 3.27 per cent.

Energy consumption in Mexico in the period 1973-77 is reported in detail in Table V.8., whence it can be seen that the largest share of commercial energy was consumed, in the last few years, in the form of hydrocarbons, both as liquid (about 60 per cent) and gaseous (20 - 24 per cent) fuels. The total share of hydrocarbons consumed was about 82 per cent of the total commercial energy utilized. For 1974, the utilization of total hydrocarbons produced can be summarized as follows:

- 69 per cent for public consumption (of which 44 per cent was for industrial use, 40 per cent for transportation, 16 per cent for domestic use).
- 15 per cent utilized by processing and refining crude petroleum and/or natural gas.
- 16 per cent for electricity production.

In 1974, domestic coal production was utilized as follows:

- 71 per cent for metallurgical production
- 27 per cent for public consumption
- 2 per cent for electricity production.

Furthermore, almost all the coal imported in the same year (10 per cent of the amount produced or 9 per cent of the total coal consumed in the country) was utilized in metallurgical plants.

All the hydropower was utilized for the generation of electricity. Among the developing countries, Mexico has a high per capita consumption of electricity (751 kWh in 1976 - see Table V.4.). Per capita consumption for the developing countries and the world stands at 305 and 1720 kWh, respectively. In 1974, the electricity produced was utilized as follows:

- 33 per cent by industry
- 23 per cent for transportation and commerce
- 22 per cent domestic uses
- 6 per cent public lighting
- 16 per cent losses during transmission.

2. National energy resources

Mexico is a country rich in energy resources. Of the developing countries in the region, it has perhaps the most favourable energy resource prospects by virtue of its hydrocarbon resources (both oil and gas). These were recently discovered and have already turned Mexico into an oil-exporting country.

Prospects in the coal sector are also positive: however, it is expected that in the near future production will be limited to satisfying local demand. Recent discoveries have revealed very high potentials. There are also positive prospects for the utilization of hydropower on a larger scale. Hitherto only 25 per cent of the country's hydroelectric potential has been exploited, yet its further exploitation will depend on the country's economic development.

Given the intense volcanic activity in Mexico, the prospects for the exploitation of this particular form of energy are very positive, despite the modest degree of development in this sector at present. Uranium reserves are also estimated to be extensive.

Petroleum reserves

Following the first oil discoveries in the Chiapas-Tabasco area in 1972, the estimates of Mexican oil reserves have been completely revised. Different prognoses have been made: some describe Mexico as one of the oil-richest countries in the world, while other, more conservative estimates speak of large, but not enormous reserves (still in the order of tens of billions of barrels). At present, the situation is not completely clear, but the latest information does provide a better picture of the country's potential.

During the last seven years, Pemex has continuously corrected its estimations upwards about the Mexican oil potential, always showing great caution when declaring reserves: in 1974 the national reserves were estimated at 3.5 billion of barrels of oil. In 1976, the estimates of proven reserves increased to between 11 and 14 bb, although the Pemex technicians indicated a figure of about 60 bb as being a more probable indication of total oil and gas reserves. In September 1978, Mexican President Lopez-Portillo announced that Mexico had potential hydrocarbon reserves equivalent to 200 billion barrels of oil (by way of comparison, total reserves in the Persian Gulf are estimated at 400 billion barrels).

The newly discovered oil fields lie in an area bounded by a geological reef, located partially on the main land and partially off shore. At present, only a part of this area has been exploited for oil production, mainly in the region of Chiapas-Tabasco. Pemex carried out a seismographic survey in the Chiapas-Tabasco area and located about 150 potential oil deposits. Of these, only about one third have been investigated by exploratory drilling, and 25 proved to be rich oil fields.

Pemex technicians also found that five or six oil-producing geological structures were linked together comprising a huge potential oil field of more than 200 square kilometres. As of the middle of 1978, they were still trying to establish the limits of this field which was yielding 9,000 barrels daily, even though drilling was supposed to be on the extreme periphery.

In the Gulf of Campeche, Pemex has found even more potential off-shore oil deposits. Its Director General said "we have mapped over 200 seismic structures appreciably larger than those of Reforma. Should they be oil-bearing, they would dwarf the potential of Chiapas-Tabasco" (where Reforma is placed). Hitherto of ten potential structures identified, seven have been shown to be rich in oil.

A large portion of the country has yet to be subjected to any accurate geological surveys in the quest for oil. Some estimates indicate that Pemex technicians will require at least five or more years in order to appraise the limits and potential of recent discoveries.

<u>Gas reserves</u>

The potential reserves of natural gas in Mexico are directly linked to oil reserves. Consequently, estimates of reserves have also been revised upwards in the recent years. The gas reserves are included in the figure of 200 billion barrels of oil equivalent that the Mexican President Lopez-Portillo announced in September 1978 as the national potential reserves. Even if it is rather difficult to predict accurately which fraction of the total hydrocarbons reserve is accounted for by gas, a figure of about 30 per cent of the total can be estimated. In the Reforma area, the fields offer a high gas/oil ratio: the estimated potential gas reserves for this area are of the order of 20 trillion cubic feet (≈ 3.9 billion barrels of petroleum equivalent).

The most important recent gas discoveries were made in the states of Nuevo Leon and Coahuila in the central part of northern Mexico. It should be emphasized that these states are not normally considered to be rich in hydrocarbons. Thus, there are grounds for optimism in respect of possible future discoveries.

Moreover, offshore drilling in the Gulf of Campeche has proved the presence of gas reserves associated with oil. There are also good prospects for the natural gas discovered in the Baja California peninsula. The presence of gas has already been detected during offshore drilling, and it is hoped that the fields might extend to the mainland.

Coal reserves

The "coke crisis" of the past few years has forced Mexico to increase its endeavours to be increasingly self-sufficient in the production of coal in order to meet the country's needs (more than 70 per cent of the total coal supply is utilized in the steel and iron industry as metallurgical coke). For this reason, the Government has launched a programme to locate new coal reserves. Included is a study of the properties of "cokization" of national coal in order to ensure supplies of a satisfactory quality.

In the case of Mexico, the estimated reserves are so extensive that greater attention is being paid to the possibility of its use for energy production. Coal reserves are estimated to lie between 6 and 10 thousand million metric tons, comparable with the extent of the oil and gas reserves. Of the reserves 1,685 million tons are proven, 462 probable and 5,992 potential. The bulk thereof is concentrated in the State of Coahuila.

Hydroelectrical rsserves

The Mexican hydroelectrical potential reserves have been differently estimated by various authors. Some data from the year 1974 show a potential for new power generation of 21,800 MW which, at that time, represented about five times greater than the capacities of hydro-electric power plants (4,500 MW). More recent figures in reference from 1976 indicate a total of 16,785 MW hydroelectric reserves divided as follows: 1,375 MW in power plants under construction, 3,780 MW planned, and other 11,620 MW in possible sites. In 1977 the reserves were quoted as 13,833 MW, 10,000 MW were suitable for development. [16]

This notwithstanding, the possibility of development in this particular sector has decreased following the recent oil discoveries. The large capital investment required for hydropower stations makes them less attractive to a developing country such as Mexico which can obtain oil at production costs.

Geothermal reserves

The geothermal potential in Mexico is not yet well established, but it is thought to be high. In the area of Cerro Prieto, where the only Mexican geothermal power plant is located, investigations have been carried out. The results indicate a potential of some 400 MW for this area over a period of 30 years. Moreover, some 120 other zones suitable for geothermal steam production have been detected. These are mainly located in the central belt of the country.

Uranium reserves

Mexico has not extracted uranium recently; however, an estimate has been made of the country's nuclear fuel reserves. Up to December 1975, proven reserves were some 6,000 tons (expressed as $U_2 O_3$) plus a further 2,000 tons of probable reserves. However, many experts feel these figures are bound to increase when more accurate investigations are carried out, since to date only one per cent of the country has been surveyed.

Non-commercial energy reserves

Accurate investigations have been carried out in Mexico on the distribution of solar radiation [17, 18]. The results confirm the large potential: more than one half of the country's total surface area receives radiation ranging from 4.6 to 5.8 kWh/m^2 per day, with 37 per cent of the surface area being subjected to radiation of more than 5.8 kWh/m^2 per day.

Some applications on a small scale have already been utilized, primarily water pumps in arid territories, and in principle 25,000 wells could be equipped with these devices. Other applications - always in the agricultural sector - have already been scheduled. The use of agricultural wastes also offers good prospects. It has been calculated [18] that the potential production of methane by means of the anaerobic fermentation of these residues could be as high as two or three times the present energy consumption of the country.

3. National energy policies

The recent oil discoveries have contributed to the recent improvement in the economic situation of Mexico. In 1975, Pemex was able to produce more oil than the domestic market required and started exporting.

Pemex was set up as a national oil company in place of the foreign companies, when energy resources were nationalized by the Mexican government in 1938. In the past few years, the government oil strategy has hinged upon the ability of national bodies (represented by Pemex which receives almost one fifth of the national budget) to develop a solid national oil industry. With its 40 years experience, the national oil company has shown itself capable of surrounding the problem. Most of the drilling and prospecting has been carried out by Pemex engineers in collaboration with consultants and technicians from U.S. companies which also provided some of the technical services and rigs.

The investment and development programmes drawn up by Pemex are very ambitious: by 1982, Pemex plans capital expenditures of $16.5 million. This investment policy will be maintained only if oil production increases at the rate predicted in the last years. So far this goal would seem feasible, since the Pemex Director-General announced that daily production will reach 2.25 million barrels by 1980 two years earlier than envisaged. The revenue accruing from oil exports are very important to the Mexican economy, even though Mexico has been very successful hitherto in obtaining loans to support the development of its oil extraction industry. This possible improvement in the economic situation may lead to two important developments:

(1) Improved living standards for Mexicans in general, and, in particular, for the poorer segments of the population; and

(2) Possible development of all potential energy resources.

At present, the latter development would seem to be one of the prime objectives of the Government's energy strategy. However, the economic and material tasks implicit in the achievement of such an objective are very onerous for a developing country such as Mexico. Offshore oil production illustrates this point well: the present offshore oil production of the Pora Rica fields comes from 11 small platforms in shallow water with gas lines linking each platform to the mainland. However, the future exploitation of the Gulf of Campeche offshore oil fields will call for the operation of at least 50 platforms in waters up to 140 m deep using completely different, and more complex, gas and oil collection systems.

There is every indication that as the economy of the country becomes more stable, Mexico will adopt a more conservative attitude towards its oil reserves, following the example of Venezuela which has pursued this policy for the last 20 years with positive results. Diaz Serrano, the Director of Pemex, said that "On reaching the production target in 1980, Mexico will be able to decide whether to proceed at the same production rate, or to increase or reduce production". The President of Mexico, Lopez-Portillo, has often repeated that Mexican oil resources will be exploited to the benefit of Mexico alone. It seems likely that part of this benefit will derive from selling surplus oil, thus increasing revenues.

However, even in the exports sector some problems could arise in connexion with the gas production associated with oil. Domestic demand for gas is not very high, and once met (and this should happen soon), large amounts of gas will become available, since the new oil fields already in operation have a high gas content (some 35 per cent). Apart from the possibility of flaring, the only feasible alternative seems to pipe it to the bordering countries, since the present costs of liquefaction for shipping gas overseas are too high.

4. Future energy demand

Predicting the energy situation for a rapidly developing country such as Mexico is a much harder task than for other developing areas. The prospects opened up by the recent discoveries can easily upset all the extrapolations and forecasts of the last few years, which had not taken into account this sudden evolution in the energy situation.

An initial rough estimate can be made by extrapolating the future energy demand on the basis of the increase in energy consumption in the period 1950-75, which on an average was 7.34 per cent per year. Extrapolating this figure yields an estimated consumption of 158 t.c.e. in 1985 and 456 million in 2000. The reliability of such an estimation, however, can be deduced from the previous observation while, in the period 1974-76, the annual rate of growth was only 1.6 per cent as a result of the world energy crisis and the consequent oil price increase.

In 1974, J. Lartigue, Head of the Nuclear Science Department of the University of Mexico, prepared an interesting study on a national energy model [19]. He estimated that the growth in energy consumption would be very high: an increase of 9.65 per cent per year. Consequently, he estimated that energy consumption would be 195 million t.c.e. in 1985 and 777 million t.c.e. in 2000.

A draft prepared by scientists working at IIASA (International Institute for Applied Systems Analysis) on future energy demand for world regions [5] quoted different figures: the average annual growth rate in the period 1975-2000 is calculated at 4.6 per cent. According to Ref. [16] the energy consumption in year 2000 will lie between 407 and 527 million t.c.e., the derived average annual growth rate being 7.9 per cent. The figures for 1985 present a factor spread of 1.6, while the corresponding figures for year 2000 differ by a factor of 3.2.

The cumulative energy demand obtained as a sum of the yearly future energy demand from 1979 onwards varies from 645 to 929 million t.c.e. if extended to 1985, and from 3,985 to 7,800 million t.c.e. if extended to year 2000. In the first case, the factor spread is 1.44, in the second 1.95.

The forecasts present a wide range mainly because of the situation peculiar to Mexico: the country has had its potential energy reserves increased by immense orders of magnitude in less than four years. The subsequent general optimism produced an inversion of the general negative trend which hitherto had indicated a decrease in the present and future energy consumption growth rate. In the case of Mexico, the favourable prospects for the future production of energy reduce the importance of large fluctuations in the range of energy consumption forecasts.

In terms of environmental conservation, industrialization can substantially contribute to environmental degradation. The potential problems deserve close examination.

5. Future national energy problems

The Mexican energy reserves and possible future energy demand up to year 2000 have been described in some detail in the previous paragraphs. From the data quoted conclusions can be drawn as to the national energy resources demand of Mexico, at least up to the beginning of the next century.

The highest estimate reported for the cumulative national demand of energy between 1979 and 2000 was in the order of some 7,800 million t.c.e. Even in this case, national energy reserves cover to a large extent possible future demand. If only the proven fossil fuel reserves are taken into account, the ratio between reserves and cumulative energy demand up to 2000 is almost 2. If potential reserves are included, this ratio increases to 5.

Moreover, Mexico also has considerable reserves of renewable and non-commercial energy which, if exploited, could already meet the country's energy demand.

As a consequence, the energy problems of Mexico in the future will be related not so much to the supply of energy, but to the exploitation, utilization, and conservation of national energy reserves, as well as to the related environmental impact.

The energy policy will be directly connected with the pattern of development chosen. For a developing country richly endowed with natural resources such as Mexico, the tendency to promote rapid industrialization through utilization of energy is very marked.

Table V.1. Mexico: production of primary energy
(Millions of metric tons of coal equivalent)

	Total primary commercial energy	Liquid fuel	Gas	Solid fuel	Primary[1/] hydro and geo electricity	Nuclear electricity	Fuelwood[2/]	Total primary energy
1950	18.200	15.170	1.225	0.942	0.863	-	N.A.	N.A.
1960	32.621	22.030	6.527	1.776	2.288	-	N.A.	N.A.
1970	60.269	35.106	15.571	2.959	6.633	-	N.A.	N.A.
1973	66.147	38.292	16.617	4.263	7.245	-	3.668	70.085
1974	78.164	48.212	17.189	5.166	7.597	-	3.617	81.781
1975	88.771	59.022	17.642	5.193	6.914	-	3.501	92.272
1976	97.107	66.432	17.189	5.650	7.845	-	3.501	100.608
1977		74.044	16.898	6.000				

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.44 t.c.e. (efficiency of 27.8 %).

2/ Calorific value: $3x10^6$ Kcal/m^3.

Table V.2. Mexico: crude petroleum balance and refinery capacity
(Millions of metric tons of coal equivalent[1/])

	Total petroleum production (including off shore)	Off shore petroleum production	Import	Export	Addition to stocks	Apparent supply	Refinery capacity
1950	10.155	-	-	1.700	0.835	7.620	9.560
1960	13.889	-	-	0.150	0.060	13.679	16.050
1970	21.501	1.791	-	-	-0.769	22.270	30.250
1973	23.257	1.922	3.183	0	0.19	26.250	37.490
1974	29.594	2.555	1.350	0.294	0.735	29.915	37.490
1975	36.456	2.942	0	5.500	0.646	30.310	38.720
1976	41.336	3.300	0	6.176	4.660	30.500	47.870
1977	46.700						

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ 1 petroleum metric ton assumed 1.47 t.c.e.

Table V.3. Mexico: energy trade
(Millions of metric tons of coal equivalent)

	1973	1974	1975	1976
Crude petroleum				
Import	4.679	1.984	0	0
Export	0	0.432	8.085	9.079
Energy balance (Exp.-Imp.)	-4.679	-1.552	+8.085	+9.079
Energy petroleum products				
Import	5.172	3.511	4.089	4.536
Export	0.762	2.229	0.498	0.286
Energy balance (Exp.-Imp.)	-4.277	-1.282	-3.591	-4.250
Natural gas				
Import	0.473	0.400	0.328	0.274
Export	0.340	0.068	0.014	0
Energy balance (Exp.-Imp.)	-0.133	-0.332	-0.314	-0.274
Solid fuel				
Import	0.356	0.519	0.542	0.174
Export	0.001	0.002	0.001	0.001
Energy balance (Exp.-Imp.)	-0.355	-0.517	-0.541	-0.173
TOTAL				
Import	10.680	6.414	4.959	4.984
Export	1.236	2.731	8.598	9.366
Energy balance (Exp.-Imp.)	-9.444	-3.683	+3.639	+4.382

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table V.4. Mexico: production, trade and consumption of electricity
(Thousand millions of kilowatt hours)

	Total production	Import	Export	Total consumption	Per capita consumption (in kWh)	Per capita installed capacity (in kW)
1950	4.423	0.125	-	4.548	173	0.047
1960	10.813	0.487	0.033	11.267	313	0.085
1970	28.608	0.186	0.037	28.757	567	0.146
1973	37.061	0.398	0.035	37.424	666	0.168
1974	40.772	0.383	0.040	41.115	707	0.168
1975	43.298	0.378	0.090	43.586	725	0.186
1976	46.612	0.340	0.140	46.812	751	0.206

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table V.5. Mexico: production of electricity by type
(Thousand millions of kilowatt hours)

	Total production				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	4.423	2.474	1.949	-	0.874	0.695	0.179	3.549	1.779	1.770
1960	10.813	5.639	5.174	-	2.250	2.041	0.209	8.563	3.598	4.965
1970	28.608	13.615	14.993	-	3.418	3.233	0.185	25.190	10.382	14.808
1973	37.061	20.688	15.383	-	3.923	3.742	0.181	33.138	16.946	16.192
1974	40.772	23.599	17.173	-	4.102	3.920	0.172	36.670	19.669	17.001
1975	43.298	27.671	15.627	-	3.903	3.737	0.166	39.395	23.934	15.461
1976	46.612	28.833	17.729	-	3.750	3.582	0.168	42.862	25.301	17.561

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table V.6. Mexico: installed capacity of power plants
(Thousands of kilowatts)

	Total capacity				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	1235	628	607	-	224	170	54	1011	458	553
1960	3048	1691	1357	-	727	627	100	2321	1064	1257
1970	7414	4084	3330	-	1385	1293	92	6029	2791	3238
1973	9444	5835	3609	-	1718	1630	88	7726	4205	3521
1974	9749	6077	3672	-	1378	1302	76	8371	4775	3596
1975	11211	7016	4195	-	1381	1305	76	9830	5711	4119
1976	12847	8156	4691	-	1387	1312	75	11460	6844	4616

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table V.7. Mexico: utilization of installed electric generating capacity
(Kilowatt hours produced per kilowatt)

	Total utilization				Industrial			Public		
	Total	Thermal	Hydro	Nuclear	Total	Thermal	Hydro	Total	Thermal	Hydro
1950	3581	3939	3211	-	3902	4088	3315	3510	3884	3201
1960	3548	3335	3813	-	3095	3255	2090	3689	3282	3950
1970	3859	3334	4502	-	2468	2500	2011	4178	3720	4573
1973	3924	3546	4537	-	2283	2296	2057	4289	4030	4599
1974	4182	3883	4677	-	2977	3018	2263	4381	4119	4728
1975	3862	3944	3725	-	2826	2864	2184	4008	4191	3754
1976	3628	3541	3779	-	2704	2730	2240	3740	3697	3804

Source: Data derived from U.N. statistics, primarily Ref. [7].

Table V.8. Mexico: energy consumption
(Millions of metric tons of coal equivalent)

	Total commercial energy consumption		Liquid fuel	Gas	Solid fuel	Primary[1] hydro and geo electricity	Nuclear electricity	Fuelwood[2]	Total energy consumption	
	Aggregate	Per capita (t.c.e.)							Aggregate	Per capita (t.c.e.)
1950	15.557	0.592	11.590	2.081	0.969	0.917	-	N.A.	N.A.	N.A.
1960	29.568	0.819	19.830	5.419	1.829	2.490	-	N.A.	N.A.	N.A.
1970	57.901	1.142	33.402	14.386	3.415	6.698	-	N.A.	N.A.	N.A.
1973	70.484	1.301	41.439	17.022	4.617	7.406	-	3.668	74.152	1.369
1974	76.552	1.318	45.545	17.575	5.684	7.748	-	3.617	80.169	1.380
1975	77.687	1.291	46.940	17.970	5.734	7.043	-	3.501	81.188	1.350
1976	82.227	1.319	51.009	17.463	5.823	7.932	-	3.501	85.728	1.375

Source: Data derived from U.N. statistics, primarily Ref. [7].

1/ Conversion factor: 1000 kW produced correspond to 0.44 t.c.e. (efficiency of 27.8 %).

2/ Calorific value: $3x10^6$ Kcal/m^3.

Chapter VI. Subregion 6: U.S. Gulf Coast

1. Present energy situation

Production of primary energy

The southern part of the United States facing the Caribbean Sea is the region producing the most energy in the United States, accounting for some 54 per cent in 1975. In Table VI.1. the energy production of the U.S. Gulf Coast is reported for the period 1972-75. In Tables VI.2. and VI.3., production, broken down by state, is given for 1972 and 1975, respectively. The bulk of this energy production comes from hydrocarbons (more than 96 per cent). However, the overall production of hydrocarbons dropped by more than 13.2 per cent in only four years (1972-75) as a result of a political decision taken subsequent to the decline in national reserves. The production of hydrocarbons did in fact surpass the annual addition to proven oil and gas reserves, arising from new discoveries. Despite the increase in exploratory activities, the prospects of a higher rate of extraction are not positive.

Oil (including liquefied natural gas) alone accounts for some 45 per cent of overall production, i.e. 46-47 per cent of the subregion production of hydrocarbons, and the Gulf Coast region produces about one quârter of the country's oil. Over the period considered (1972-75) subregional production decreased by 12.5 per cent for the reasons explained above.

The bulk of the production comes from two states, Texas and Louisiana, which account for 95.4 per cent (1975 data) of the subregional production. Texas was the main producer (62.8 per cent of the total), and its position strengthened over the period 1972-75 when production dropped by only 6.6 per cent compared with 24.6 per cent in Louisiana.

Whereas Mississipi decreased its production (by 24.2 per cent), Alabama and Florida increased their rates of extraction by 33.3 and 26 per cent, respectively. However, even then, their combined production was restricted to only one per cent of the subregion's total production.

Natural gas represents the most important energy resource in the subregion, comprising 52.2 per cent (1975 data) of the overall energy production (i.e. 53.2 per cent of the hydrocarbons production). The U.S.

Gulf Coast production is particularly important to the national energy balance since some 80 per cent of the United States' natural gas comes from this subregion. However, even for gas there has been a downward trend over the period considered, the rate of extraction dropped by 13.7 per cent in three years, even higher than that of oil. Once again, Texas and Louisiana were the bulk producers accounting for 99 per cent of the subregional production (Texas, 518 per cent, Louisiana, 45.4 per cent in 1975). In the period 1972-75, the drop in gas extraction was more marked in Texas (16.3 per cent) than in Louisiana (11.2 per cent). Although minor, production in Mississipi decreased too (by 22.7 per cent), while only Alabama and Florida were able to increase their very limited productions.

The coal situation is more positive. In the wake of the energy crisis, coal extraction increased by 35 per cent between 1972 and 1975. However, production has always been rather limited and, even after the new efforts made in the sector, energy produced in the form of coal was only three per cent out of the total. It should also be noted that only five per cent of the U.S. coal production came from the Gulf Coast subregion (1975 data). Texas and Alabama were the two coal-producing states in the subregion (32.7 and 67.3 per cent respectively), with production increasing appreciably in Texas (almost three fold in three years).

In terms of hydroelectric energy, the subregion is not particularly well endowed, as a result of which this sector's contribution to the total energy production has always been very modest (less than one per cent). Over the period considered it is difficult to identify a trend in the production of hydroelectricity since the figures presented in Tables VI.1., VI.2. and VI.3. fluctuate to a certain degree. The major producer was Alabama which accounted for some 90 per cent of the subregional production. Even though some states have good prospects in the geothermal sector, this source of energy was not utilized in the period 1972-75.

On the contrary, the nuclear production of electricity underwent a major increase between 1972 and 1975. In 1972, production was almost negligible and limited to the state of Florida. In 1973 Alabama also started production. At a subregional level, production increased more than 100-fold in three years, yet the share of electricity produced from nuclear energy remained less than four per cent. All the other states in the subregion have scheduled the construction of nuclear power stations for the near future, and by 1985 the whole area should be utilizing nuclear power.

Trade in energy and production of secondary energy

Both in energy production and trade, hydrocarbons dominated the sector. Although the net energy balance for the whole subregion was still positive in 1975, it showed a negative trend throughout the period examined. States such as Texas and Louisiana were the only net positive exporters of the subregion, even with the limitations mentioned above. In the oil sector, Texas suffered a marked decrease in its exports and shifted from an oil exporter in 1972 to an importer three years later. However, this was the consequence of a reduction in state oil production and an increase of the state refinery capacity. By 1975 net imports of crude oil accounted for some 35 per cent of the oil supplied to the refineries in the subregion.

The situation was also negative in Louisiana where oil exports decreased and imports increased, with a drop in net exports of more than 72 per cent between 1972 and 1975. However, up to 1975 the oil balance of the subregion was still positive, despite a decrease of more than 86 per cent in comparison with 1972.

Natural gas exports also decreased, albeit not as rapidly as for oil (13.8 per cent over the period considered). Once again Texas and Louisiana were dominant in the trade balance, and most of the gas was transported through pipelines.

As for the coal trade, the balance was negative for the whole subregion. In 1975, only Alabama exported coal equivalent to 7.5 per cent of its production, whereas it imported 4.5 times the amount of coal exported. However, the negative balance for coal only slightly affected the overall subregional energy balance, since the rest is dominated by hydrocarbons.

The subregion was a net exporter of electricity (8.7 billions of kWh in 1975). Except for Mississipi, all the other states exported electric energy.

As for energy processing, refinery and gas processing capacity in the subregion is high. In 1975, the region had 74 of the 256 refineries in the U.S.A. The corresponding crude-oil processing capacity was of the order of some six billion barrels per day: 40 per cent of the national total. Most of the plants were located in the main oil-producing states: Texas and Louisiana together accounted for 93.7 per cent of the subregion's refinery capacity.

The situation was even more positive in respect of gas processing: in 1975, 482 plants processed 53,221 million cubic feet per day. By way of comparison the U.S. national capacity in the same year was 72,697 million cubic feet per day.

Production of electricity

Over the period 1972-75, the production of electricity in the region increased by some ten per cent, at an average annual growth rate of 3.4 per cent. This trend is shown in Table VI.7., while Tables VI.8. and VI.9. give a breakdown for 1972 and 1975, respectively.

The bulk of production was generated thermally (between 92 and 96 per cent over the period considered) with a particular reliance on gas which was utilized to produce some 56 per cent of the region's electricity output (1975 data). However, over the period considered, this method of production showed a negative trend dropping more than six per cent in three years.

The reverse was the case in respect of oil and coal. Coal, in particular, was used for some 20 per cent of production, increasing more than 67 per cent in four years. The reason for this trend lies in a policy directed towards the conservation of less abundant energy resources (in this case gas) which led to some gas-fired power plants being converted to coal.

This shift was particularly significant for states such as Texas or Mississipi which were almost entirely dependent on gas for electricity production. Texas, which in 1972 had produced more than 98.6 per cent of its electricity from gas, has since reduced this dependency to 89 per cent through the introduction of coal, which had never been utilized before 1973. A similar pattern is to be observed in Mississipi. Hydropower has also experienced an upswing (27 per cent in three years); however, its contribution to total production remained at some four per cent.

The situation was much more favourable in the nuclear sector which increased its production appreciably (110 times in four years). The contribution of this form of energy to electricity production totalled some 3.3 per cent in 1975, whereas it had been almost negligible in 1972. The per capita electricity consumption of the subregion was comparatively high (10,460 kWh in 1972 increased to 10,912 in 1975), above U.S. average (9,911 kWh in 1975).

Consumption of energy

Globally speaking, the Gulf Coast of the United States is one of the areas with the highest energy consumption in the country. This is particularly true of those states, which produce the largest amounts of energy.

In Tables VI.10., VI.11. and VI.12. the energy consumption is reported for the period 1972-75 by state. These data show a decrease in per capita energy consumption until 1974 (some four per cent in two years) followed by an upswing in 1975 (four per cent in one year) which brought consumption back to its 1972 level.

As usual, hydrocarbons had the greatest share in consumption. Gas, in particular, was utilized in large amounts. However, the trend confirmed by data of Table VI.1. was to reduce the use of gas despite the increase in consumption, oil and coal being the main substitutes. Oil consumption increased rapidly in 1975 (29 per cent over the previous year), after a slight decrease between 1972 and 1974. It was mainly utilized in the industrial sector. Coal consumption increased constantly (37.7 per cent in four years) at an average annual growth rate of 11.2 per cent. As for the consumption of hydro and nuclear electricity, the pattern was the same as that described previously.

An examination of consumption patterns in the individual states reveals that the energy-rich states (Texas and Louisiana) mainly utilized gas, with considerable reliance on oil. For the other states, the consumption pattern was a little more diversified (e.g. Alabama consumed more coal than any other fuel) or, at least, more oriented towards the use of oil.

The distribution of the use of energy in the different sectors and for the different states in 1975 is shown below:

	Texas	Louisiana	Mississipi	Alabama	Florida
	(Percentage for each sector)				
Residential and commercial	7.7	6.5	17.2	9.9	7.5
Industrial	50.9	64.4	29.9	30.2	9.8
Transportation	20.7	16.2	34.1	22.3	39.0
Electric utilities	20.7	12.9	18.8	37.6	43.7
Total	100.0	100.0	100.0	100.0	100.0

2. National energy resources

Of the areas within the United States, the Gulf Coast area is relatively well endowed with energy resources, mainly in the form of hydrocarbons, with oil and gas being unevenly distributed among the states of the region. This notwithstanding, these reserves cannot guarantee the subregion self-sufficiency in terms of energy supply, even though it is only a part of the countries. Unless new discoveries are made, prospects in the hydrocarbons sector do not seem too positive. As for coal, the subregion has some potential but this has not been adequately exploited to date.

In respect of hydropower, the picture is rather negative since most of the reserves have already been exploited and, in any event, this form of energy is not particularly abundant in the region. There are good prospects in the geothermal sector (bearing in mind its intrinsic limits), as for uranium reserves. Consideration might also be given to the use of agricultural waste and alternative energies in general.

Petroleum reserves

Crude oil reserves have continuously decreased over the past few years because of the high degree of exploitation of the wells, yet reducing the rate of extraction would only partly check this negative trend. The largest oil reserves - not only in the region but in the United States as a whole (except for Alaska) - are located in Texas and Louisiana which together account for some 40 per cent of the national reserves. The most recent estimations of proven oil reserves in the subregion are reported in Ref. [20] and the situation as of 31 December 1978 is given below:

	Texas	Louisiana	Mississipi	Alabama	Florida	Total
			(Millions of barrels)			
Proven reserves 31 Dec. 1978	7,689.991	2,893.401	187.587	33.107	169.361	10,973.447
Change from 31 Dec. 1977	-777.445	-220.008	-15.045	-11.067	-39.388	-1,062.953
Indicated added reserves	1,244.023	46.425	27.255	4.000	1.050	1,322.753

If it is recalled that oil production in 1975 totalled 1974.7 million barrels, the situation does not appear very positive.

However, Ref.[21] quoted other reserves which, though defined as "ultimate", could be taken to be potential reserves. The global figure quoted of 71,952 million barrels of crude oil is broken down as follows: 70.6 per cent in Texas, 25.6 per cent in Louisiana, 2.5 per cent in Mississipi and less than one per cent in Alabama and Florida.

To these oil reserves should be added the reserves of natural gas liquids which constitute a substantial contribution to the hydrocarbons reserves. Ref. [20] reports the most recent proven reserves at 31 December 1978 as follows:

	Texas	Louisiana	Mississipi	Alabama	Florida	Total
			(Millions of barrels)			
Proven reserves 31 Dec. 1979	2,398.787	1,350.360	15.127	215,442	20.221	3,999.937
Change from 31 Dec. 1978	-130.503	-34.815	-2.420	-11.377	+1.269	-177.846

By way of comparison, the production of natural gas liquids in 1975 amounted to 434.6 million barrels.

Gas reserves

The situation in terms of natural gas reserves is not very different from that described for oil and natural gas liquids. Once again, Texas and Louisiana have the largest reserves, amounting to 55 per cent of all the national gas reserves, and Ref. [20] quotes the most recent estimates of proven reserves, which are shown below by state:

	Texas	Louisiana	Mississipi	Alabama	Florida	Total
			(Billions of cubic feet)			
Proven reserves 31 Dec. 1978	62,157.836	52,685.970	1,307.133	745.538	215.323	117,111.800
Change from 31 Dec. 1977	-7,557.601	-3,011.822	+103.381	+5.681	-55.027	-10.515.388

The ultimate reserves of gas quoted in Ref. [21] are of the order of 463,000 billion cubic feet, distributed as follows: 58.0 per cent in Texas, 40.4 per cent in Louisiana, 1.3 per cent in Mississipi, and 0.3 per cent between Alabama and Florida.

Coal reserves

Coal reserves in the subregion are not very significant when considered on a national scale. Even in subregional terms, the production of coal is not of particular relevance. Only two states have some coal reserves: Alabama and Texas. The former's proven reserves are estimated at some 2,782 million tons (of which 1,755 are bituminous coal and 1,027 lignite), while the latter's reserves are somewhat large, 3,272 million tons of lignite. In toto, the subregion has 6,054 million tons of coal reserves (coal production in 1975 was 33.6 million tons).

Even if coal assumes greater importance in the future energy scenario of the United States, it seems unlikely to take on particular relevance for the Gulf Coast states which are traditional consumers of hydrocarbons, in particular gas. Moreover, since the subregion only has 1.3 per cent of the national reserves, it is probable that any re-evaluation of coal as energy resource will benefit the coal industry of other more richly endowed states.

Hydroelectric reserves

For hydropower the prospects of large-scale utilization are also limited. The subregion cannot count on any significant hydropower resources. Even though resources are not completely exploited, only few sites remain for future utilization. The estimated potential scarcely exceeds 3,000 MW of new installed capacity, and most of these reserves are concentrated in the state of Alabama.

Geothermal reserves

All the geothermal resources of the subregion are concentrated in Texas, and the estimated recoverable potential has been assessed at some 9,000 million t.c.e. Drilling work for geopressure wells has already started, and it is calculated that by the year 2000 the state could have a power plant producing some 1,600 MW.

Uranium reserves

Texas is the only state with active uranium deposits, apart from Florida which has uranium deposits in its phosphates reserves. Texas also has milling facilities. However, throughout the period considered, no uranium was produced in the subregion, and no specific data on the extent of the uranium reserves in the subregion were found.

Non-commercial energy reserves

By virtue of its geographical position, the subregion would appear the area best suited in the U.S.A. to the utilization of solar energy. Although technological and economic constraints exist for present day large-scale commercial applications, the level of research and the large amount of capital available show future promise for the large-scale use of solar energy.

Furthermore the possibility of using agricultural and urban wastes is already given. According to Ref. [21] some 50 million dry tons of agricultural residue are generated yearly and, assuming a calorific value of 4.400 kcal/kg, energy of the order of 32 million t.c.e. could be recovered.

The agricultural residue generated annually and the corresponding potential energy production are given below:

	Agricultural residues	Available energy
	(million t.c.e.)	
Texas	16.270	10.226
Louisiana	10.429	6.555
Mississipi	8.719	5.480
Alabama	10.232	6.431
Florida	5.820	3.658
Total	51.470	32.350

Energy from agriculture sources could also be obtained by converting pastures, forest and open ranges to biomass farms. A study quoted in Ref. [21] reports that if this were to be accomplished for only 10 per cent of the total potential, the energy thus recovered would be some 93 million t.c.e. for the whole southern region of the U.S.A. (i.e. including other states not in the Gulf Coast region). A rough estimate of the recoverable energy for the Gulf Coast subregion alone would be some 50 million t.c.e.

3. National energy policies

The autonomy of the five states of the U.S. Gulf Coast in energy and environmental matters is limited by the central authority. However, several Federal agencies have operated at a regional level on different problemsoof environment control, energy resources, etc. This situation is relatively new, since up until a few years ago institutions in the individual states dealing with these kinds of problems were isolated, and failed to work together, and in some cases they did not exist at all. Only with the emergence of problems subsequent to the energy crisis and the rapid increase in oil prices in 1973 was there a pronounced growth in legislation and regulatory activity. Each state has introduced its own laws or regulations, most of which are based on Federal legislation.

However, since energy policies at a national level are still at an evolutionary stage, each state has drawn up specific laws to deal with the problems arising out of the different economic patterns of development, environmental situation, energy problems, etc.

As a part of one of the most industrialized countries in the world, the Gulf Coast subregion has consumed large amounts of energy over the past few years, and in some states consumption was even higher than the national average. The dramatic impact of the energy crisis has brought about a revision of all development programmes and introduced a different perspective. New concepts, such as energy conservation, reduction of consumption, and alternative energies, have not only appeared in legislation or energy programmes, but they have also been accepted generally. However, because of the inertia of the system, considerable time will elapse before these concepts really affect the situation. Certain steps have been taken at both the national and state level: energy conservation policies have been introduced; oil and gas extraction limits have been set to prevent too rapid a depletion of the reserves of; and research into, and studies on, possible alternative energies has been stepped up.

4. Future energy demand

The future energy situation of the subregion is inexorably linked to that of the whole country. In order to evaluate the future energy demand of the subregion, a model covering the whole country could be adapted to the subregional level. However, in this report, forecasting is based exclusively on an extrapolation of the consumption data of recent years (1950-75) coupled with extrapolations of the population growth based on past experience.

This work has already been done and reported in Ref. [5]. For the purposes of this report, the only significant data that can be derived therefrom is the annual average growth rate estimated at 2.19 per cent, on the basis of which energy consumption for the whole region is estimated at 665 million t.c.e. in 1985 and at 920 million t.c.e. by the year 2000 (these figures are based on 1975 energy consumption data).

Broken down by state the figures read as follows:

	Texas	Louisiana	Mississipi	Alabama	Florida	Total
			(Millions of t.c.e.)			
Estimated consumption in 1985	338	140	30	73	84	665
Estimated consumption in 2000	468	193	43	100	116	920

In respect of electric energy consumption, the same source reports an average annual growth rate of 2.92 per cent; consumption would thus amount to 441 kWh in 1985 and to 678 billion kWh in the year 2000. The cumulative overall energy consumed in the region between 1979 and 1985 should be in the order of 3,750 million t.c.e., and the corresponding figure up to the year 2000 should be some 72,297 million t.c.e.

5. <u>Future national energy problems</u>

As stated above, most of the energy problems confronting the U.S. Gulf Coast cannot be solved at a subregional level, but have to be placed in a broad national context. Consequently, it would be meaningless to compute the possibility of an individual subregion attaining self-sufficiency. (In any event, on comparing the data on future energy consumption in the subregion and available resources, the prospects are still negative).

The United States is the greatest consumer of energy in the world, and since 1971 its foreign oil imports have doubled. Consequently, the main energy problems will relate, on the one hand, to means of meeting growing domestic demand and, on the other hand, to limiting energy consumption. The first problem is a matter of politics and is beyond the scope of this paper, whereas the second point has already been accommodated in certain national and regional measures of various kinds based on the following points:

- Conservation incorporating a more efficient use of energy in the various industrial and domestic sectors;
- Conversion of some of the industrial plants and power facilities which at present use oil or coal to the use of energy resources that are more readily available on the domestic market (primarily coal and nuclear fuels);
- Control of the rate at which domestic non-renewable energy resources are exploited;
- Reduction of oil imports through increased prices;
- Promotion of the development of alternative energy resources.

Table VI.1. U.S. Gulf Coast: production of primary energy
(Millions of metric tons of coal equivalent)

	1972	1973	1974	1975
Total commercial energy	1253.0	1248.1	1186.0	1105.8
Liquid fuels	568.9	556.7	526.9	497.6
Gas fuels	654.8	658.2	621.5	565.0
Solid fuels	24.8	26.1	27.5	33.6
Primary 1/ hydro and geo electricity	4.5	5.2	4.7	5.4
Nuclear 1/ electricity	0.0	1.9	5.4	4.2
Fuelwood 2/	N.A.	N.A.	N.A.	N.A.
Total primary energy	N.A.	N.A.	N.A.	N.A.

Source: Ref. /21/.

N.A. = not available.

1/ Conversion factor: 1000 kWh produced correspond to 0.38 t.c.e. (efficiency of 32 %).

2/ Calorific value: $3x10^6 Kcal/m^3$.

Table VI.2. U.S. Gulf Coast: production of primary energy by state (1972)
(Millions of metric tons of coal equivalent)

	Total commercial energy	Liquid fuels	Gas fuels	Solid fuels	Primary[1/] hydro and geo electricity	Nuclear electricity
Texas	689.4	334.8	350.3	4.0	0.3	-
Louisiana	514.7	215.4	299.3	-	-	-
Mississipi	17.2	12.8	4.4	-	-	-
Alabama	27.2	2.1	0.2	20.8	4.1	-
Florida	4.5	3.8	0.6	-	0.1	0.0
TOTAL	1253.0	568.9	654.8	24.8	4.5	0.0

Source: Ref. [21].

1/ Conversion factor: 1000 kWh produced correspond to 0.38 t.c.e. (efficiency of 32 %).

Table VI.3. U.S. Gulf Coast: production of primary energy by state (1975)
(Millions of metric tons of coal equivalent)

	Total commercial energy	Liquid fuels	Gas fuels	Solid fuels	Primary[1/] hydro and geo electricity	Nuclear electricity
Texas	617.3	312.6	293.0	11.0	0.7	-
Louisiana	428.0	162.4	265.6	-	-	-
Mississipi	13.1	9.7	3.4	-	-	-
Alabama	32.4	2.8	1.4	22.6	4.6	1.0
Florida	15.0	10.1	1.6	-	0.1	3.2
TOTAL	1105.8	497.6	565.0	33.6	5.4	4.2

Source: Ref. /21/.

1/ Conversion factor: 1000 kWh produced correspond to 0.38 t.c.e. (efficiency of 32 %).

Table VI.4. U.S. Gulf Coast: trade in energy
(Millions of metric tons of coal equivalent)

	1972	1973	1974	1975
Crude petroleum				
Imports	88.1	108.7	129.8	151.3
Exports	207.5	192.2	179.7	167.6
Energy balance	+119.4	+83.4	+49.9	+16.3
Natural gas				
Imports	406.8	402.6	361.4	347.8
Exports	723.7	712.0	656.4	620.9
Energy balance	+316.9	+309.4	+295.0	+273.1
Solid fuel				
Imports	N.A.	14.6	13.9	14.6
Exports	N.A.	1.4	1.0	1.7
Energy balance	N.A.	-13.2	-12.9	-12.9

Source: Re-elaboration of data presented in Ref. [21].

Table VI.5. U.S. Gulf Coast: trade in energy by state (1972)
(Millions of metric tons of coal equivalent)

	Texas	Louisiana	Mississipi	Alabama	Florida	TOTAL
Crude petroleum						
Imports	51.9	17.7	16.5	1.7	0.3	88.1
Exports	93.6	102.0	6.3	1.7	3.9	207.5
Energy balance (Exp.-Imp.)	+41.7	+84.3	-10.2	0.0	+3.6	+119.4
Natural gas						
Imports	0	35.6	240.9	119.8	10.5	406.8
Exports	137.3	249.2	227.7	109.5	-	723.7
Energy balance (Exp.-Imp.)	+137.3	+213.6	-13.2	-10.3	-10.5	316.9
Solid fuel						
Imports	-	-	N.A.	N.A.	N.A.	N.A.
Exports	-	-	N.A.	N.A.	N.A.	N.A.
Energy balance (Exp.-Imp.)	-	-	N.A.	N.A.	N.A.	N.A.

Source: Re-elaboration of data presented in Ref. [21].

Table VI.6. U.S. Gulf Coast: trade in energy by state (1975)
(Millions of metric tons of coal equivalent)

	Texas	Louisiana	Mississipi	Alabama	Florida	TOTAL
Crude petroleum						
Imports	92.3	39.2	17.1	2.4	0.3	151.3
Exports	89.1	62.2	5.3	2.4	8.6	167.6
Energy balance (Exp.-Imp.)	-3.2	+23.0	-11.8	+0.0	+8.3	+16.3
Natural gas						
Imports	-	31.1	208.2	99.5	9.0	347.8
Exports	112.8	215.8	202.2	90.1	-	620.9
Energy balance (Exp.-Imp.)	+112.8	+184.7	-6.0	-9.4	-9.0	+273.1
Solid fuel						
Imports	-	-	1.5	7.7	5.4	14.6
Exports	-	-	-	1.7	-	1.7
Energy balance (Exp.-Imp.)	-	-	-1.5	-6.0	-5.4	-12.9

Source: Re-elaboration of data presented in Ref. [21].

Table VI.7. U.S. Gulf Coast: production of electricity by type
(Thousand millions of kilowatt hours)

	TOTAL	Thermal			Hydro	Nuclear
		Oil	Gas	Coal		
1972	299.3	51.7	197.2	39.1	11.2	0.1
1973	320.0	58.0	193.5	47.8	13.7	5.0
1974	327.1	58.0	183.6	59.2	12.1	14.2
1975	331.0	55.8	184.4	65.4	14.3	11.1

Source: Re-elaboration of data reported in Ref. [21].

Table VI.8. U.S. Gulf Coast: production of electricity by type and by state (1972)
(Thousand millions of kilowatt hours)

	TOTAL	Thermal			Hydro	Nuclear
		Oil	Gas	Coal		
Texas	130.7	1.0	128.9	-	0.8	-
Louisiana	39.3	0.7	38.6	-	-	-
Mississipi	12.1	1.9	10.2	-	-	-
Alabama	49.8	0.3	0.2	39.1	10.2	-
Florida	67.4	47.8	19.3	-	0.2	0.1
TOTAL	299.3	51.7	197.2	39.1	11.2	0.1

Source: Re-elaboration of data presented in Ref. [21].

Table VI.9. U.S. Gulf Coast: production of electricity by type and by state (1975)
(Thousand millions of kilowatt hours)

	TOTAL	Thermal			Hydro	Nuclear
		Oil	Gas	Coal		
Texas	147.8	2.9	131.8	11.2	1.9	-
Louisiana	39.2	3.8	35.4	-	-	-
Mississipi	11.5	5.3	2.9	3.3	-	-
Alabama	54.7	0.3	0.5	39.0	12.2	2.7
Florida	77.8	43.5	13.8	11.9	0.2	8.4
TOTAL	331.0	55.8	184.4	65.4	14.3	11.1

<u>Source</u>: Ref. [21].

Table VI.10. U.S. Gulf Coast: consumption of energy
(Millions of metric tons of coal equivalent)

	Total commercial energy		Liquid fuels	Gas fuels	Solid fuels	Primary[1/] hydro and geo electricity	Nuclear[1/] electricity
	Aggregate	Per capita (t.c.e.)					
1972	506.028	17.685	199.770	274.815	26.878	4.540	0.025
1973	510.022	17.481	194.875	279.594	27.947	5.691	1.915
1974	504.389	16.955	192.211	271.602	31.018	4.122	5.436
1975	535.688	17.636	248.187	239.879	37.015	5.428	4.179

Source: Ref. /21/.

1/ Conversion factor: 100 kWh produced correspond to 0.38 t.c.e. (efficiency of 32 %).

Table VI.11. U.S. Gulf Coast consumption of energy by state (1972)
(Millions of metric tons of coal equivalent)

	Total commercial energy		Liquid fuel	Gas fuel	Solid fuel	Primary [1] hydro and geo electricity	Nuclear [1] electricity
	Aggregate	Per capita (t.c.e.)					
Texas	281.052	23.922	113.611	166.260	0.846	0.335	-
Louisiana	88.859	23.771	16.207	72.652	-	-	-
Mississipi	24.772	10.980	10.415	14.357	-	-	-
Alabama	54.292	15.412	13.626	10.523	26.032	4.111	-
Florida	57.053	7.765	45.911	11.023	-	0.094	0.025
TOTAL	506.028	17.685	199.770	274.815	26.878	4.540	0.025

Source: Ref. [21].

1/ Conversion factor: 100 kWh produced correspond to 0.38 t.c.e. (efficiency of 32 %).

Table VI.12. U.S. Gulf Coast: consumption of energy by state (1975)
(Millions of metric tons of coal equivalent)

	Total commercial energy		Liquid fuel	Gas fuel	Solid fuel	Primary[1/] hydro and geo electricity	Nuclear[1/] electricity
	Aggregate	Per capita (t.c.e.)					
Texas	272.322	22.225	119.664	145.404	6.534	0.720	-
Louisiana	112.482	29.670	46.548	65.934	-	-	
Mississipi	24.537	10.459	14.712	8.482	1.343	-	-
Alabama	58.197	16.103	18.202	9.734	24.624	4.622	1.015
Florida	67.150	8.046	49.061	10.325	4.514	0.086	3.164
TOTAL	535.688	17.660	248.187	239.879	37.015	5.428	4.179

Source: Ref. [21].

1/ Conversion factor: 100 kWh produced correspond to 0.38 t.c.e. (efficiency of 32 %).

APPENDIX 1

This summary, which was extracted from an ECE publication [22], is designed to provide an overview of the techniques adopted for energy production, handling and storage, and of their impact on the environment. Only those items of interest to the problems of the wider Caribbean have been summarized.

Open-cast mining of solid fuels
Technological aspect

1.1 Present technology

Principle: the over-burden is removed mechanically to uncover seams. In order to avoid flooding of the mine, regularization or diversion of water-courses is often necessary. Once mining has been completed, the site can be rehabilitated or developed for other uses.

Economic efficiency: greater than for underground mines (lower capital expenditure, higher technical efficiency, higher possibilities of adaptation and expansion and less time required to bring the mine into operation).

1.2 Future technology

Primarily, rationalization of production and development of means of reducing the impact on the environment.

2. Methods for reducing environmental impact

(i) Air pollution: debris may be covered with waste rock or with a layer of humus, which is then re-sown or re-timbered.

(ii) Water pollution: hydrogeological surveys taken before the commencement of mining operations, and careful planning of mining.

(iii) Rehabilitation or development of the site: the site may be filled with suitable materials - an operation which requires detailed studies - and returned to agriculture, forestry, etc. Large depressions may also be transformed into artificial water reservoirs for recreation or for urban, industrial or agricultural purposes (water supply, irrigation, etc.). Estimates made in the United States indicate that complete rehabilitation seems to increase the cost of producing coal by about $US 0.16 to 2.91 per ton (1977).

3. General assessment

This mining technology is likely to be widely used particularly for coal because of its economic efficiency (lower investment and operating costs than for underground mines) and also because of a revival of interest in coal for the production of electricity.

Open-cast mining of solid fuels
Environmental aspect

1. Air pollution

Exhaust gases from machines, exidation products, dust raised by machines or by the wind. Tips containing a high percentage of inflammable substances are liable to spontaneous combustion. If the fire cannot be controlled in time, these tips can produce combustion gases for several decades.

2. Water pollution

Mainly caused by an accelerated erosion of the excavated material: pH changes, salts, particulates, etc.

3. Land use

Considerable. The area excavated is very seriously affected (total destruction of fauna and flora, and the surroundings are spoiled by tips, diversion of water courses, access roads, etc. ...).

4. Solid waste

Very large quantities (tips). Can be used for subsequent rehabilitation.

5. Noise

Fairly high during ripping of the over-burden and operations (caterpillar loaders, crushers, etc.). Detonations when explosives are used. Persons most seriously affected are the mine workers themselves.

6. Aesthetic aspect

Serious problem: excavated areas, tips, roads, etc. Can be eliminated, when mining has been completed, by rehabilitation of the site.

7. Others

None.

8. General assessment

Serious environmental effects. However do not present insoluble problems so long as the necessary precautions are taken (air and water pollution). When mining has been completed, the site can be rehabilitated or developed so as to eliminate, in the long term, all the land use and aesthetic problems.

Offshore extraction of oil and gas
Technological aspect

1. Present technology

Methods: large platforms are built on the continental shelf, wells are drilled and the extracted oil or gas is transported to the sea-shore by pipelines or stored (for oil) in large floating reservoirs. Associate gases are either transported by pipelines, re-injected into the oil-bearing bed, processed at the platform (very expensive technology but desirable from the environmental point of view); flared (current practice but dangerous for platform equipment and creates air pollution problems) or burnt under the sea in special devices (new technology). Methods for increasing oil and gas production (pp. 38-39) can generally be applied.

Economic efficiency: lower economic efficiency compared to onshore oilfields resulting from a very complicated and expensive technology requiring rather large investments.

2. Methods of reducing environmental impact

There are no specific methods for offshore oilfields but the use of traditional methods, associated to safety measures is considerably more complicated. Methods have been developed in order to reduce the probability and the effects of potential oil spills at offshore platforms. Problems of the disposal of associate gas, drilling muds, brines and used water are very complicated from an environmental point of view. Generally muds, brines or used water should be re-injected into the oil-bearing formation.

3. General assessment

Offshore methods of oil and gas extraction have become a very important technology now that world oil recovery from the sea-bed has reached 20 per cent of total oil recovery. These methods will be widely used in the future.

Offshore extraction of oil and gas

Environmental aspect

1. Air pollution

Mostly combustion products or flared associated gases and, in case of oil spill, evaporation of lighter hydrocarbon fractions.

2. Water pollution

Offshore production of gas should not create particularly significant problems when compared to offshore production of oil. Several major oil spills occurring at platforms have been reported and their effects on the marine environment and fisheries activities often extensively studied. Oil being biodegradable, rare and small-scale oil spills can be overcome through bacterial degradation. Large oil spills have a significant impact on marine flora and fauna and might affect the water cycle. If diluted in sea water, brines may have an econological effect on surrounding marine communities.

Special attention and measures seem to be required during oil exploration in arctic and sub-arctic regions where the environment may be particularly sensitive and where, apparently, potential climatic disturbances might be induced by large-scale oil spills over and under ice by modifying the albedo.

3. Land use

Irrelevant.

4. Solid wastes

None to negligible.

5. Noise

No specific information but probably of minor importance except for staff working at the platform.

6. Aesthetic aspect

Fairly important problems due to derricks and harm to amenities, particularly beaches, in case of oil spill (tourism).

7. Others

Navigation safety; explosion and fire risks in case of important leaks.

8. General assessment

No acute problem with gas extraction. By contrast, oil extraction might lead to important environmental problems requiring special care and advanced technologies. Particular attention should be devoted to arctic and sub-arcti areas where environmental effects are still unclear and deserve further research.

Gas pipelines
Technological aspect

1.1 Present technology

Pressurized (55-75 bars) gas is transported over long distances by pipes of a diameter up to 1,420 mm, mostly buried at about 1 m in depth, especially when crossing arable land. Sectionalizing valves are provided at about 30 km intervals and compressor stations (gas turbines) needed roughly every 100 km.

Economic efficiency: large capital investments required. For long distances and on the basis of equal heat energy transported, gas pipelines are economical when compared with electricity and solid fuel transportation, but more costly than liquid fuel transportation.

1.2 Future technology

Pipes of larger diameters, higher pressures and lower temperatures will be used (a pressure rise from 55 bars to 75 bars increases through capacity by 30 to 35 per cent; at a given operating pressure, cooled natural gas (-65 to -70°C) doubles the transport capacity; liquefied natural gas at 40-45 bars increases capacity 3 to 4 times).

2. Methods for reducing environmental impact

There are no important environmental problems. By careful routing, cutting down trees and the risks of explosion can be reduced to a minimum.

3. General assessment

Natural gas transportation by pipeline will increase. Under present technical conditions, a gas pipe of about 900 mm diameter corresponds to the transportation of about 1,000 tons/hr of other fuels by roads, highways or inland waterways.

Gas pipelines
Environmental aspect

1. Air pollution

   Very limited (compressors' exhausts if gas fired) during normal operation.

2. Water pollution

   None during normal operation.

3. Land use

   When the pipeline is buried, there are limited land use restrictions (proximity of buildings): these in general increase with the pressure of the system, the land can be returned to its former use as soon as construction is completed. Compressor stations, reception terminals and regulator stations are the only above-ground facilities. Land requirements are therefore very limited.

4. Solid waste

   None.

5. Noise

   Localized to regulating, metering and compressor stations (exhausts, air intake, engines and compressors, heat exchangers, blowdown). Compressor stations are generally located in rural areas and existing regulations specify that compressor noise level in residential areas should not exceed 35-40 db.

6. Aesthetic aspects

   Very limited if pipes can be buried. No trees on the right of way.

7. Others

   Explosion risks in case of important and sudden leaks.

8. General assessment

   No important environmental problems.

Oil[1]-fired power plants

Technological aspect

1.1 Present technology

Method of electricity production: the heat produced in the combustion chamber of the boiler vaporizes water and super-heats steam. The thermal energy is converted in the turbine into mechanical energy which is in turn converted into electric energy by a generator.

Thermal efficiency: 35-36 per cent seems near the maximum technically feasible.

Economic efficiency: depends on the fixed costs (initial investment) and variable costs (fuel, maintenance, labour and taxes). The cost of electric power produced in plants of this kind varies from country to country.

1.2 Future technology

Increased thermal conversion efficiency.

2. Methods for reducing environmental impact

(i) optimization of combustion so as to minimize the amounts of CO and NO produced;

(ii) desulphurization of the fuel oil and combustion gases; use of fuels with a low sulphur content;

(iii) partial utilization of the waste heat for district heating (combined production of heat and electric power); cooling towers. (But aesthetic impact; assisted draught towers seem to be a better answer.)

3. General assessment

Recent price increases for oil products in the world market have seriously affected the cost of the electricity produced in oil-fired plants. As a result, interest has shifted to other types of power station, in particular hydro-electric and nuclear power plants.

1/ Standard fuel oil is composed of C:83.3 per cent, H:10.9 per cent, O:2.2 per cent and S:3.6 per cent, and produces about 40,000 kJ (9,600 kcal) per kg.

Oil-fired power plants

Environmental aspect

1. **Air pollution**

Total emissions about 76,000 tons per annum for a modern 1,000 MWe plant burning 1.6 million tons of oil per year.

Aldehydes	0.2 kg/tce	Sulphur	13.5 kg/tce
CO	traces	Particulates	0.3 kg/tce
Hydrocarbons	0.3 kg/tce	Radioactivity	nil
NO_x	8.9 kg/tce		

2. **Water pollution**

Total: 3,000 to 6,000 tons per annum for a 1,000 MWe power plant

Thermal pollution: about 60 per cent of the energy consumed;
Biological fouling of condensers and cooling towers;
Chemical pollution: nil for the power plant itself except if biocides are used;
Radioactive pollution: nil.

3. **Land use**

About 4 km^2 for a 1,000 MWe power plant (without ancillary facilities).

4. **Solid waste**

Nil or negligible.

5. **Noise**

Not very serious (30 db at 100 m from the power plant); occasional whistling, audible up to a distance of 5 km, from the pressure regulators.

6. **Aesthetic aspect**

A serious problem due to chimney stacks, cooling towers and outside installations (storage tanks, railway lines, high-tension lines, etc. ...).

7. **Others**

Land use planning problems.

8. **General assessment**

The environmental problems raised by oil-fired power plants are fairly considerable from more than one point of view (in particular air pollution), but seem to be less serious than the problems inherent in coal-fire plants.

Gas-fired power plants[1/]

Technological aspect

1. Present technology

Method of electricity production: the heat produced in the combustion chamber of the boiler vaporizes water and super-heats steam. The thermal energy is converted in the turbine into mechanical energy, which is in turn converted into electric energy by a generator.

Thermal efficiency: 35-36 per cent seems near the maximum technically feasible (without gas turbines).

Economic efficiency: the market price of gas determines the extent to which it is used for electric power production. Although it is generally reserved as a basic product for industrial purposes, natural gas can, in producing countries, be competitive with other fuels in electric power production. For importing countries, the production of electric power from natural gas may prove to be uneconomical.

2. Methods for reducing environmental impact

(i) optimization of combustion in order to minimize the amounts of CO and NO_x produced;

(ii) desulphurization of the fuel gas and combustion gases; use of fuels with a low sulphur content;

(iii) partial use of waste heat for district heating (combined production of electric power and heat); cooling towers (but aesthetic impact; assisted draught towers seem to be a better answer).

3. General assessment

Natural gas does not play a very important role in the production of electric power, and (barring the discovery of massive deposits) it is not likely to do so in future either. In the majority of cases, its use in thermal power plants has been decided upon not for purely economic reasons, but in order to protect the environment.

1/ There are various types of gas (blast furnace gas, industrial gas, gas obtained from coal gasification, petroleum gas, natural gas, etc. ...). The gas most widely-used in the electricity industry is natural gas, the usual composition of which is: CH_4 (methane): 94.0 per cent, C_2H_6: 1.2 per cent, C_3H_8: 0.7 per cent, C_4H_{10}: 0.4 per cent, C_5H_{12}: 0.2 per cent, N_2: 3.3 per cent, CO: 0.2 per cent and SH_2 normally in slight traces. Its calorific value is about 35,000 kJ/m^3 (8,560 kcal/m^3) standard at 15° (nm^3) and its specific weight is 0.765 kg/nm^3.

Gas-fired power plants

Environmental aspect

1. Air pollution

Total emissions: about 24,000 tons per annum for a 1,000 MWe power plant

Aldehydes	0.06 kg/tce	Sulphur	0.1 - 0.2 kg/tce
CO	negligible	Particulates	0.9 kg/tce
Hydrocarbons	negligible	Radioactivity	nil
NO_x	20.9 kg/tce		

2. Water pollution

Total: About 1,000 tons per annum for a 1,000 MWe power plant

Thermal pollution: about 60 per cent of the energy consumed;
Biological fouling of condensers and cooling towers;
Chemical pollution: none from the power plant itself except if biocides are used;
Radioactive pollution: nil.

3. Land use

About 4 km^2 for a 1,000 MWe power plant.

4. Solid waste

None.

5. Noise

Not a very serious problem; occasional whistling, audible up to a distance of 5 km.

6. Aesthetic aspect

A fairly serious problem due to the chimney stacks, cooling towers and outside installations (high-tension lines, etc. ...).

7. Others

Installation of gas pipe-lines in urban areas (choice of emplacement, safety, etc. ...). Land use planning.

8. General assessment

Relatively limited environmental problems, except as regards waste heat and possible use of biocides. The environmental problems raised by gas-fired power plants, although not negligible, seem to be substantially less serious than those raised by coal or oil-fired plants.

High calorie[1/] coal fired power plants
Technological aspect

1.1 Present technology

Method of electrical generation: the heat produced in the combustion chamber of the boiler vaporizes water and super-heats steam. The thermal energy is converted in the turbine into mechanical energy which in turn is converted into electric energy by a generator.

Thermal efficiency: 35-36 per cent seems near the maximum technically feasible.

Economic efficiency: depends on the price of coal in the countries considered. Coal can be competitive and will, in future, have a role to play in electric power production.

1.2 Future technology

Fluidized bed combustion; new heat transfer media; development of combined cycles of higher efficiency using gas turbines.

2. Methods of reducing environmental impact

(i) optimization of combustion in order to minimize the amounts of CO and NO produced;

(ii) desulphurization of coal and combustion gases; use of fuels with a low sulphur content;

(iii) de-dusting of the smoke (possible up to 99.8 per cent);

(iv) ash tips raise environmental problems. The possibilities of using ashes in other economic sectors is under examination;

(v) partial use of waste heat for district heating; cooling towers (but for aesthetic impact, assisted draught towers seem to be a better answer).

3. General assessment

Coal now plays, and will continue to play, a very important role in the production of electricity. Protection of the environment and improved working conditions involve considerable expenditure, which affects the cost price of this source of energy. Also, high-calorie coal can be used with greater efficiency in other industrial sectors.

1/ Coal whose combustion releases 25,000 - 30,000 kJ/kg (6,000-7,000 kcal/kg) and would typically be composed of C: 67.9 per cent, H: 0.8 per cent, N: 1.5 per cent, S: 0.5 per cent, H_2O: 9 per cent and ash 15.5 per cent.

High calorie coal-fired power plants

Environmental aspect

1. Air pollution

Total emissions: about 165,000 tons per annum for a modern 1,000 MWe power plant

Aldehydes:	traces	Sulphur	14.7 kg/tce
CO	0.1 kg/tce	Particulates	2.0 kg/tce
Hydrocarbons	0.2 kg/tce	Radioactivity	traces
NO_x	9.1 kg/tce		

2. Water pollution

Thermal pollution: about 60 per cent of the energy consumed;
Biological fouling of condensers and cooling towers;
Chemical pollution: none, except if biocides are used;
Radioactive pollution: none.

3. Land use

About 4 km^2 for a 1,000 MWe power plant (storage and access facilities not included).

4. Solid waste

About 500,000 tons for operating a 1,000 MWe plant (slag).

5. Noise

Not very serious (30 db at 100 m from the power plant); occasional whistling, audible up to a distance of 5 km, from the pressure regulators. However, transport devices, such as cranes, conveyor belts, etc. could be noisy.

6. Aesthetic aspect

Problems due to the size of the installations, the height of the chimney stacks and cooling towers, and also the outside installations and ash tips. Often constructed in the industrial zones of cities.

7. Others

The choice of sites is largely determined by the availability of cooling water and the transportation of large quantities of coal. Normally such power plants are close to mine complexes when cooling water is available.

8. General assessment

The environmental problems raised by coal-fired power plants and their technological requirements (industrial infrastructure, land, corridors for high-tension lines, cooling, high chimney stacks, rail access, ash tips, etc. ...) are particularly serious from several points of view (air pollution, planning, etc.).

Pressurized light-water reactors
Technological aspect

1.1 Present technology

Method of electrical generation: heat is produced by a controlled and maintained fission chain reaction using a fuel enriched in fissionable U-235. Ordinary (light) water is used as a coolant and at the same time acts as moderator. To achieve a high coolant outlet temperature without boiling, the system must be highly pressurized (about 160 kg/cm^2). A massive steel pressure vessel is used to contain the reactor core. The coolant is circulated through a number of primary loops containing steam generators and pumps. The resulting steam then drives turbo-generators.

Conversion efficiency: about 32 per cent.

1.2 Future technology

No dramatically new feature is to be expected. Present trends are toward providing increased safety and higher conversion efficiency by augmenting water temperature in the reactor vessel. Offshore plants.

2. Methods for reducing environmental impact

- contaminated air from nuclear installations is delayed before being released into the atmosphere in order to allow the decay of short-lived isotopes. Particularly harmful nuclides are trapped in filters or recovered.
- several methods for the management of highly radioactive wastes are envisaged. The most appropriate seems to be storage in salt deposits.
- partial recovery of waste heat for low grade energy utilization.
- increased overall efficiency by the combined production of electricity and heat for district heating and industrial purposes.
- increased safety measures.

3. General assessment

Investment costs and the availability of enriched fuel are probably the two main economic factors which will influence the future development of nuclear power. Pressurized light-water reactors are therefore sensitive to both issues. This type of reactor will however probably continue to represent the major share of the total nuclear installed capacity in the ECE region. It is furthermore increasingly recognized that problems of waste disposal or reprocessing will influence, in a decisive manner, future nuclear strategies.

Pressurized light-water reactors

Environmental aspect

1. Air pollution

Total: about 6,000 tons of materials and about 490,000 Ci of radioactive materials released yearly during the full fuel cycle (incl. mining, etc.) powering a 1,000 MWe station.

Non-radioactive pollutants are mainly dust and particulates emitted during mining operations and exhaust gases from mining, transport, etc. equipment as well as some fluorine released during the enrichment step.

Radioactive pollutants are mainly tritium, Kr85, I^{129} and I^{131}. Amounts released at the power plant are low and vary notably with the cladding materials used (f. ex. 0.4 Ci of tritium/MWe per year with zircaloy and up to 17 Ci with stainless steel). Noble gases such as Kr^{85} are difficult to retain, while most of I^{129} and I^{131} is trapped in filters. The largest part of radioactivity is released at the reprocessing plant and is constituted of short-lived radio-nuclides which therefore do not accumulate in the atmosphere. On the other hand, tritium, Kr^{85} and I^{129} have longer half-lives and do accumulate in the environment.

2. Water pollution

Total: about 21,000 tons of materials and 3,000 Ci of radioactive materials released yearly during the full fuel cycle for a 1,000 MWe power plant. Thermal pollution: about 2/3 of the gross thermal output. Cooling towers are commonly used. Significant heat discharges also occur during the enrichment step.

Biological fouling: mainly in condensers and cooling towers.

Chemical pollution: some at the mining and refining stages. None at the power plant except if biocides are used.

Radioactive pollution: slight to negligible at the power plant, moderate at the reprocessing plant. Major long-life nuclides released are tritium, Sr90, Ru^{106} and Ce^{144}.

3. Land use

About 77 km^2 for all operations (complete fuel cycle).

4. Solid waste

About 2,600,000 tons released yearly during the full fuel cycle powering a 1,000 MWe station, mostly non-radioactive mining wastes and about 140 billion Ci of highly-compact radio-active wastes, the management of which is still at the research stage. Plutonium is recovered for use in breeder reactors.

5. Noise

Considered of minor importance. Comparable to fossil-fuelled power plant operations.

6. Aesthetic aspect

Significant problem due to the size of installations, cooling towers, open air facilities, transformers, etc. Generally built in rural areas as a safety measure.

7. Others

- Land use planning;
- Safety concerns expressed by the public and part of the scientific community;
- Non-proliferation questions;
- Decommissioning.

8. General assessment

The evaluation of the relative importance of some environmental factors listed above mainly depends nowadays on general attitudes towards economic policies; this is therefore not a matter answerable by the secretariat. From a purely technical point of view it can be said that a probably harmless low-level radioactive pollution is unavoidable during normal operation and that the problem of long-term disposal of highly radioactive wastes has still not found a solution which seems unequivocably satisfying from the economic, political, technical and environmental standpoints.

Boiling light water reactors
Technological aspect

1.1 Present technology

Method of electrical generation: heat is produced by a controlled and maintained fission chain reaction in a fuel enriched in fissionable U-235. Ordinary (light) water is used as a coolant and at the same time acts as moderator. Water is allowed to boil and produce steam at about half the system pressure of a pressurized light water reactor (PWR) (about 70 kg/cm^2). This lower operating pressure allows a thinner walled but larger reactor vessel. Steam directly drives turbogenerators, and is then cooled in a condenser and recirculated through the reactor core.

Conversion efficiency: an average 33 per cent of the gross thermal output of BWR is converted into electricity.

Economic efficiency: comparable to PWR.

1.2 Future technology

Similar to PWR.

2. Methods for reducing environmental impact

Similar to PWR.

3. General assessment

Very comparable assessment as for PWR.

Boiling light water reactors
Environmental aspect

1. Air pollution

   Same remarks as for PWR. At the plant site, BWR are releasing less tritium but more noble gases (Kr^{85} and various isotopes of Xe).

2. Water pollution

   Same remarks as for PWR. Radioactive pollution at the power plant site is virtually zero.

3. Land use

   Similar to PWR.

4. Solid waste

   Same remarks as for PWR.

5. Noise

   Same comment as for PWR.

6. Aesthetic aspect

   Comparable with PWR.

7. Others

   Same features as for PWR.

8. General assessment

   Comments made about PWR are also valid for BWR. It can in addition be stated that at the power plant site and in normal operation the radioactive contamination of the environment is lower than with PWR.

Hydro power plants
Technological aspect

1.1 Present technology

Method: dams retain water creating a reservoir and a fall (kinetic energy) which activates turbines producing electricity. Dams situated in mountainous areas, such as the Alps, create high pressure falls producing large quantities of electricity with relatively small amounts of water. This type of power plant is very flexible and is often used as an energy storage capacity for meeting peak demands. On the other hand, dams situated across rivers utilize large amounts of flowing water for producing electricity and are particularly suitable for meeting basic load needs.

Efficiency of conversion: 75 to 95 per cent.

Economic efficiency: demonstrated. Large investment but no fuel costs. Often associated with flood control, watercourses regulation and irrigation.

1.2 Future technologies

(a) very large facilities flooding huge areas;

(b) "micro-hydro" facilities for meeting local needs.

2. Methods for reducing environmental impact

Dams which stop fish migration paths have special canals with "stairs" which allow fish to progressively jump over the obstacle. No other method seems applicable.

3. General assessment

Hydropower is one of the oldest energy technologies ever developed.

Hydro power plants
Environmental aspect

1. Air pollution

   None, except during the construction phase (dust, exhaust gas, etc.).

2. Water pollution

   Decreased auto-purification capacity of the water body. Proliferation of anaerobic bacteria in water bodies which are already polluted.

3. Land use

   May be considerable.

4. Solid waste

   None, except during the construction phase.

5. Noise

   None.

6. Aesthetic aspect

   Varies considerably from site to site. Potential fish killing when passing through turbines. Diversion of watercourses. Sometimes contributes to the improvement of touristic potentialities of the areas concerned.

7. Others

   Hazards from dam failure. Accidental oil releases from turbines and transformers. Barriers to fish migration. Social impact when communities or large territories are flooded. Potential local climatic changes (wind pattern and speed, increased evaporation, change in ground albedo). Potential seismic effect due to the weight of water. Silting.

8. General assessment

   Small scale application of hydropower creates only marginal environmental problems and seems preferable to large scale schemes. Can be considered as environmentally compatible.

High voltage transmission lines
Technological aspect

1. Present technology

Method: electricity is transported through overhead cables at high voltages sometimes over long distances. Power plants are usually interconnected through networks of power transmission lines which allows flexibility in generating plant location and operation.

Economic efficiency: a 200 mile long (322 km), 345 kV line transmits power with more than 98 per cent efficiency.

1.2 Future technology

Three new technologies for underground power transmission are being studied in addition to ways of improving conventional overhead lines: (a) transmission cables insulated with compressed gas; (b) cryogenic transmission lines; (c) super-conducting transmission lines.

However, underground cables now available often have too low a transmission capacity to replace overhead lines. Underground lines are limited by the inability of the ground to absorb heat produced in the cable but special sand fills and/or water cooling overcomes this problem.

2. Methods for reducing environmental impact

Underground high voltage transmission lines would reduce unfavourable aesthetic aspects although in some cases, underground lines seem to sterilize more land than when using towers and overhead cables.

3. General assessment

Overhead transmission lines are reliable, easy to repair and efficient.

Underground transmission may replace overhead lines in certain situations where overhead transmission is impossible (offshore power plant) or unsafe, such as at intersections of lines with super-highways, airport runways or in urban areas, or in situations where the visual environment deserves such a protective measure.

High voltage transmission lines
Environmental aspect

1. Air pollution

   None.

2. Water pollution

   If used as insolating material,PCBs could accidentally be released from transformers at both ends of the transmission line.

3. Land use

   Considered as a major problem, as a significant amount of land is required. Overhead transmission lines typically require 12 acres per mile (30,000 m^2/km).

4. Solid wastes

   None.

5. Noise

   Slight whistling.

6. Aesthetic aspect

   Can be serious (unsightly).

7. Others

   Safety concerns for human beings and large birds.

8. General assessment

   The public reaction to the presence and appearance of overhead high tension lines is an important factor. This seems to be the major obstacle to the use of such facilities, although concerns have also been expressed with respect to human health and the protection of wild fauna.

Methods of increasing gas or oil extraction efficiency
Technological aspect

1. Present technology

Methods:

(i) Injection of water: the formation is maintained under pressure by pumping water into it. Depending on the type of oil, this increases oil recovery up to 50 per cent as compared to 20-30 per cent by primary methods. This method is not effective for high viscosity oils.

(ii) Additives: chemicals are added to increase the effectiveness of the pumped water method. Depending on the characteristics of the oil, geological formation, penetrability of oil-bearing bed and some other factors, the following water additives are used: surfactants, polymers, amonia, carbon dioxide, colloid of silicon oxide, etc. These additives are usually used in combination with other techniques (edging technique, changes of water pressure and régime, selection of number and place of input and output wells, etc.) and allow an increase in oil recovery from 50-55 per cent to 65-70 per cent.

(iii) Injection of high pressure air or gas (up to 640 atm.).

(iv) Thermal methods: such as, for example, injection of steam, *in situ* combustion of oil, etc. (heat effect).

(v) Shaft methods: allow increased oil extraction to 50-60 per cent, and, in combination with thermal methods, up to 90 per cent.

(vi) Combinations of these methods.

The same methods are used to increase gas and gas condensate outputs.

Economic efficiency: Most of the methods listed above (except shaft method) have a high economic efficiency: they increase the productivity of wells and the total oil output. The shaft method is less efficient.

1.2 Future technology

Underground nuclear explosions.

2. Methods for reducing environmental impact

Depending on the technology used to enhance extraction, a great number of protection measures can be taken to eliminate air and water pollution. These include various methods of water and solvents refining and recycling, refinery systems of associated gas and systems of associated gas injection into wells.

3. General assessment

Since the primary methods of oil extraction allow the recovery of only 20-30 per cent of an oil deposit, and taking into account the scarcity of oil reserves, all methods of increasing oil output will continue to be further developed and widely used in the future in oil-producing countries of the region.

Methods of increasing gas or oil extraction efficiency
Environmental aspect

1. Air pollution

   No specific information available. Should be of minor importance and varying with the technique used.

2. Water pollution

   Important chemical pollution in case safety measures would fail when chemicals such as surfactants, ammonia or silicone derivatives would be used in the vicinity of a water body. Used water should be refined and recycled, or re-injected into the geological formation.

3. Land use

   No specific information available; should be minor.

4. Solid wastes

   Minor problem (containers, etc.).

5. Noise

   No specific information; probably minor problems except for workers.

6. Aesthetic aspect

   No specific information; probably no serious problems additional to those associated with regular oil drilling techniques.

7. Others

   Light seismic effects could be envisaged.

8. General assessment

   No major environmental problems seem to be associated with these techniques under normal working conditions if appropriate measures, particularly water recycling, are applied.

Geothermal power plants
Technological aspect

1. Present technology

Method of electrical generation: direct steam and/or hot water from naturally occurring or drilled wells are directed towards turbines. The use of a secondary fluid turbine (chlorofluormethanes or isobutane) can increase the efficiency. Rapid corrosion of equipment is the most important technical problem.

Conversion efficiency: 10-20 per cent.

Economic efficiency: higher economic efficiency than fossil or nuclear fuelled power plants as there is no need for sub-systems (mining, milling, transportation of fuel, etc.). Cost of installation per kW installed capacity: $US 110 (1971). Cost of 1 kWh of produced electricity: 4.86 mills (1971). Drilling wells is expensive.

2. Methods for reducing environmental impact

(i) cooling towers (1.5 to 2.5 more expensive than for conventional power plants);

(ii) brines and used waters are reinjected. Special care should be taken to avoid watercourses and aquifer pollution;

(iii) when feasible, removal of sulphur and boric acid.

3. General assessment

The present very modest utilization of geothermal energy for producing electricity is due to the scarcity of naturally occurring high grade "dry" steam and its location in remote places. In spite of the fact that geothermal energy can be considered as a partially renewable source of energy, a careful management of the geothermal "reservoir" is required if the potential is to be maintained over a long period.

Geothermal power plants
Environmental aspect

1. Air pollution

Total: 10^4 to 2.10^5 tons/year for a 1,000 MWe power plant but amounts are highly site dependent. The most usual pollutants associated with geothermal steam are SH_2, ammonia, boric acid, fluorides and traces of NO_x, particulates, some radioactive elements such as Ra -222 and Pb -210, as well as hydrogen and methane.

2. Water pollution

Total: 10^5 to 10^8 tons/year for a 1,000 MWe power plant
thermal pollution: 80 to 90 per cent of extracted energy;
chemical pollution: mainly brines (if not reinjected);
radioactive pollution: negligible.

3. Land use

About 20 km^2 for all operations (1,000 MWe)

4. Solid wastes

None.

5. Noise

Steam emerging at high pressure makes a very loud noise (more than 100 db). Important problem, particularly for workers.

6. Aesthetic aspect

Can be an important problem as geothermal energy is generally found in non industrial areas where access roads, drilling rigs, pipes, cooling towers, etc. appear.

7. Others

Potentially microseismic effects and local subsidence might appear (both unlikely when using naturally occurring sources).

8. General assessment

There is a definite "natural" impact on the environment due to the occurring nature of surface geothermal energy: flora can particularly be seriously affected; when not used, 100 per cent of the energy is released into the environment producing "natural heat pollution". Using surface geothermal energy should - in theory - improve the situation with respect to chemical pollution if methods for reducing environmental impact are used. Additional problems: noise and landscape disturbance.

Solar space heating and air conditioning
Technological aspect

1.1 Present technology

Method of production: Direct or indirect solar radiation is absorbed by a black metal sheet enclosed in one or several shallow, glass-enclosed boxes situated on the roof or on the walls of buildings (solar collector). Tubing attached to the black metal sheet carried the heating fluid (usually water) which is stored in a tank connected to a heat exchanger. When needed, water for domestic uses is circulated through the heat exchanger as well as, in advanced and still experimental devices, fluids for heat-operated air-conditioning devices. Often sophisticated systems are assisted by a heat pump.

Economic efficiency: Demonstrated. Relatively high initial capital investment. Very limited maintenance costs (circulating pump). No fuel expenses.

When space heating with normal-sized installations, an additional heat source should be planned in most areas; space heating with solar energy seems competitive with, or even cheaper than, electric heating in most geographical areas. Solar air conditioning seems at present feasible only with large-scale installations (schools, hotels, department stores, etc.).

1.2 Future technology

Technological research is mostly oriented towards increasing the conversion efficiency of solar energy into heat with the help of "selective surfaces" and to ways and means of storing large quantities of solar heat for all-the-year operation. Solar energy conversion installations capable of heating and cooling large buildings or groups of buildings are in the planning or the demonstration stage.

2. Methods for reducing environmental impact

Improvement of design in order to minimize detrimental aesthetic aspect.

3. General assessment

The wide use of solar energy for space heating seems feasible on a small to medium scale (dwellings, schools, etc.). Obvious advantages are simplicity, absence of distribution network and free energy from renewable source. Its main disadvantage is a relatively high initial capital investment. With regard to air conditioning, further research and development is required.

Solar space heating and air-conditioning
Environmental aspect

1. Air pollution

   None for solar heating. Possible accidental releases of chlorofluoromethane from certain types of solar-powered air-conditioning units.

2. Water pollution

   None.

3. Land use

   None if solar collectors are placed on roofs or walls of buildings.

4. Solid waste

   None.

5. Noise

   None.

6. Aesthetic aspect

   Minor on dispersed individual houses (collectors). Would be significant in urban areas: majority of south-oriented roofs with very similar slope and appearance. When installed on low flat-roofed buildings, solar collectors may create an ugly skyline.

7. Others

   None.

8. General assessment

   No serious environmental problems.

Biomass energy
Technological aspect

1.1 Present technology

Principle: conversion of the solar energy tapped by photosynthesis and stored in biomass (wood, sugar cane, algae, animal wastes, etc.) into chemicals which can be easily utilized particularly in the domestic sector (heating, cooking, internal combustion engines and others).

Method: anaerobic digestion of organic compounds by the successive action of various types of bacteria. The mixture produced mainly consists of methane (50 - 70 per cent) and CO_2 (25 - 35 per cent). Alcohols, principally methanol and ethanol, are intermediate in the bio-gas production process.

Economic efficiency: not fully demonstrated but seems nearly competitive to more traditional methods. Methanol used as fuel for automobiles, for instance, appears to be between 1 - 1.5 times more expensive than gasoline. Various pilot or demonstration facilities in several countries.

1.2 Future technology

"Energy farms" for growing specific plants uniquely because of their ability to easily provide the basic materials for bio-fuel production. These farms could be on land or in offshore areas.

2. Methods for reducing environmental impact

None are required.

3. General assessment

Simple and efficient method of energy production which could undoubtedly play a growing role in the area.

Biomass energy
Environmental aspect

1. Air pollution

   The combustion of methane produces air pollutants comparable to those resulting from burning natural gas. Automobiles fuelled with methanol emit, for slightly diminished performances (acceleration) and for the same mileage, about six to ten times less carbon monoxide, nitrogen oxides and unburned hydrocarbons than those consuming gasoline and require no lead additive as an anti-knock agent.

2. Water pollution

   No apparent problem. The growth of aquatic plants and algae as raw materials for the production of bio-fuels in polluted water bodies might help in solving eutrophication problems.

3. Land use

   Negligible, except in the case of energy farms.

4. Solid waste

   Residuals from the fermentation process are generally regarded as excellent fertilizers.

5. Noise

   No apparent problem.

6. Aesthetic aspect

   No serious problem.

7. Others

   Explosion hazards with tinkered bio-gas tanks. Soil depletion with inappropriate farming. Possible erosion.

8. General assessment

   The production of methane and alcohol from biomass wastes is probably the most favourable renewable energy technology from the environmental viewpoint as it provides not only a "clean energy" supply but also a potential tool for combating water pollution problems, managing organic wastes from municipal facilities, agriculture, food industries, etc., and decreasing the air pollution load from internal combustion engines.

Wind energy
Technological aspect

1.1 Present technology

Principle: Direct utilizations (sailing and water pumping) or conversion of the wind's kinetic energy into electricity. In the latter case the output of a rotor installation increases according to the cube of the wind velocity and the square of the blade length; limitations: strength of materials, production of energy is intermittent.

Methods:

(a) Horizontal-axis rotor, blades facing the wind and slow rotation speed. Approximately 40 per cent of the wind's energy is converted into electricity (theoretical maximum: 59 per cent). The largest existing installation appears to have a capacity of 2 MWe (Tvind, Denmark).

(b) Vertical-axis turbine, with two or three rigid or flexible blades turning at high speed. Wind direction is immaterial. Conversion efficiency: approximately 35 per cent. Particularly suitable for looal applications.

Economic efficiency: Investment cost from $200/kW (Tvind) to over $2,000 per installed kW. No fuel costs and low maintenance cost.

1.2 Future technology

Methods: Refinement of present techniques, increasing the size of installations by the use of stronger materials, (notably those used in aeronautical engineering), connexion to energy storage systems in order to offset the intermittent production of this form of energy.

Economic efficiency: Could probably become competitive with conventional forms of energy conversion.

Importance in region: Potentially significant, but seems to depend primarily on research and development in this field

2. Methods for reducing environmental impact

Apparently none required.

3. General assessment

Potentially an important source of energy, involving technological principles that should be further developed, particularly as regards storage methods. High conversion yield possible because of the high quality of the energy used (kinetic energy).

Wind energy

Environmental aspect

1. Air pollution

   None.

2. Water pollution

   None.

3. Land use

   Negligible.

4. Solid waste

   None.

5. Noise

   Practically none.

6. Aesthetic aspect

   Large-scale installations could disfigure sites considerably.

7. Others

   Metal blades interfere with some radio waves (particularly television).

8. General assessment

   Wind power offers many advantages from an environmental standpoint, its sole drawback being the disfigurement of sites by large-scale installations.

Utilization of ocean temperature gradients
Technological aspect

1. Present technology

Method of production: semi-submerged offshore power plants using natural differences in ocean temperatures, particularly in tropical or warm sea current areas. Surface waters of about 27°C are pumped through a heat exchanger where a "working" fluid with a low boiling point, such as ammonia, propane or chlorofluoromethanes, is vaporized by the heat from the water. The vapour expands through the turbine, which powers a generator. The expanded vapour at low pressure is then cooled in a condenser where deep (300-1,000 m) and cold (5°C) ocean water circulates and is then recycled to the heat exchanger. Maximum possible efficiency is about 5 per cent but actual efficiency would be only 2 or 3 per cent.

Economic efficiency: not demonstrated. Capital investments evaluated at about $2,100/kW for a 100 MWe plant.

1.2 Future technology

Refinement of present techniques, particularly low-pressure turbines and "working" fluids. Increased size of installations to 100 MWe or more. Long-distance sub-marine transmission of large quantities of electricity.

2. Method for reducing environmental impact

None seems applicable.

3. General assessment

The use of ocean temperature gradients for the production of electricity calls upon relatively simple techniques (except during construction). It presents the advantages over most other renewable energy technologies of requiring no energy storage facilities.

Utilization of ocean temperature gradients
Environmental aspect

1. Air pollution
None foreseeable except for leakages of heat transfer media.

2. Water pollution
Anti-fouling agents.

3. Land use
Irrelevant.

4. Solid waste
None.

5. Noise
Unknown.

6. Aesthetic aspect
Minor due to the semi-submerged character of the installation.

7. Others
Very large discharges of unusually cold water near the sea surface may affect tourism, marine communities and fisheries and may lead to an increase in absorption of solar energy of the ocean surface layers (albedo) and consequently to some potential meteorological effects. Potential development of mariculture due to the high nutrient content of deep-sea waters. Possible effects on ozone layer in case of repeated releases of chlorofluoromethanes. Large obstacle to navigation.

8. General assessment
An attractive energy technology from the environmental point of view. It seems to be the only large-scale and centralized application of renewable energy technology for the production of electricity which seems to have no significant environmental impact.

Wave energy
Technological aspect

1.1 Present technology

Principle: wind energy stored in sea waves as mechanical oscillations is converted by various technical means such as pistons into high pressure air or water which is then used for generating electricity. Other applications, notably sea water desalination, and other principles are also under examination. A power storage device is required in view of the intermittent and variable character of waves.

Economic efficiency: not demonstrated.

1.2 Future technology

Several devices using wave energy would pump sea-water atop a cliff area into large storage reservoirs. Water would flow back to sea through a classical hydroelectric plant. This system would be flexible and could be used in conjunction with other renewable sources of energy particularly wind power.

2. Methods for reducing environmental impact

Apparently none required.

3. General assessment

Suitable technology for local application or for achieving very special tasks in coastal areas, which deserves research and development support.

Wave energy

Environmental aspect

1. Air pollution

   None.

2. Water pollution

   None except if anti-fouling agents are used.

3. Land use

   Irrelevant except if storage reservoirs are used.

4. Solid waste

   None.

5. Noise

   Apparently none.

6. Aesthetic aspect

   Minor except for installations in cliff areas.

7. Others

   Power transmission to onshore facilities. Possible interference with navigation, tourism and fisheries.

8. General assessment

   Pollution-free technology which is attractive from the environmental point of view.

APPENDIX 2

This appendix describes projects which have been proposed for implementation in the Caribbean or which have already been started. It should be emphasized that the following projects are only part of a series of projects which will be more precisely defined in the later stages of implementation.

1) Title: Farm Biogas Plant - 10,000 Chicken Farm (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Trinidad, Barbados, Guyana, Jamaica, U.K.

Objectives: to determine the feasibility and best operating characteristics under local conditions of farm-based biogas units to meet:

(a) energy self-sufficiency

(b) environmentally sound waste management

Cost: U.S. $ 240,000

Period: 3 years

2) Title: The Efficient Utilization of Bagasse for the Production of Electricity (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Barbados, Guyana

Objectives: to determine the economical and technical feasibility of utilizing surplus bagasse for production of electricity, thereby reducing the demand for fossil fuels

Cost: U.S. $ 50,000

Period: 2 years

3) Title: Production of Wall board and Animal Feed from Bagasse (using solar energy). (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Barbados

Objectives: Production of wall board and animal feed utilizing the surplus bagasse accruing on account of the more efficient combustion of bagasse normally burnt for steam or power production

Cost: not determined

Period: not determined

4) Title: Acquisition of Basic Meteorological Data for Solar and Wind Power Applications. (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Puerto Rico and other Caribbean countries

Objectives: to co-ordinate and improve the collection, analysis and publication of meteorological data for use in solar and wind power projects

Cost: U.S. $ 350,000

Period: 2 years

5) Title: Establishment of National Energy Accounting Systems (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Jamaica, Puerto Rico, Barbados, Guyana, Trinidad and Tobago

Objectives: To determine energy consumption by sector, so as to assist in energy planning.

Cost: U.S. $ 714,000

Period: 1 year

6) Title: Solar Crop Driers for Rural Areas (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Guyana, Jamaica, Trinidad and Tobago, Barbados, Grenada

Objectives: The drying of crops by the use of existing sun-drying technology with suitable modifications for local conditions

Cost: U.S. $ 300,000

Period: 2 years

7) Title: Simple Solar Pumps for Rural Areas (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Trinidad and Tobago, United Kingdom

Objectives: The design, development and testing of simple pumps operated by solar flat plate collectors, development and field testing of equipment suitable for their manufacture and utilization in rural areas

Cost: U.S. $ 98,000

Period: 3 years

8) Title: Windmill Performance Evaluation Project (Ref. [23])

Proposing organization: Caribbean Science Council

Countries: Barbados, Puerto Rico, Kenia, Jamaica, Trinidad and Tobago, Grenada

Objectives: (i) To determine suitability of scale and design in given location. Power generation (national grid) - based on meteorological data.

(ii) To determine performance characteristics of chosen design in terms of the energy output/cost function.

(iii) To investigate manufacturing potential of unit.

(iv) To develop a national policy based on (i) and (ii).

(v) Operating experience.

Cost: U.S. $ 29,000

Period: 2 years

9) Title: Wind-powered Pumping Engine (Ref. /23/)

Proposing organization: Caribbean Science Council

Countries: Barbados, St. Lucia, United Kingdom

Objectives: to build and test prototype mill using local material and skills with a view to setting up a small industry

Cost: U.S. $ 30,000

Period: 1 year

10) Title: Integrated Energy System (Ref. /23/)

Proposing organization: Commonwealth Science Council

Countries: Trinidad and Tobago, Barbados, Guyana

Objectives: to provide the energy requirements of a small community/village from an integrated system drawing on several non-conventional (and conventional) energy sources, such as solar, wind, and biomass

Cost: U.S. $ 324,000

Period: 3 years

11) Title: The Utilization of Wood and/or Charcoal as Fuel and Energy Sources for Domestic Use and Small Industries (Ref. /23/)

Proposing organization: Commonwealth Science Council

Countries: Guyana

Objectives: To carry out a comprehensive survey and to catalogue existing and readily available equipment for small domestic and small industries (up to 1 MW) uses

Cost: U.S. $ 50,000

Period: 1 year

12) Title: Identification and Effecting of Energy Savings in the Industrial Sector, Aiming Towards National Energy Conservation Policies

Proposing organization: Commonwealth Science Council

Countries: Barbados, Jamaica, Trinidad and Tobago, Guyana, Cyprus, Puerto Rico

Objectives: to examine the efficiency of major energy users in participating countries, e.g. sugar, bauxite, hotel industries

Cost: U.S. $ 581,000

Period: 1 year

13) Title: Energy Efficiency of Cooking (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Trinidad and Tobago, Barbados, Bangladesh

Objectives: to study the cooking process and arrive at designs of cooking methods and cookers that will minimize the energy consumption in cooking

Cost: U.S. $ 51,000

Period: 2 years

14) Title: Wave Energy Resources (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Trinidad, Barbados

Objectives:
(a) to investigate the wave energy potential in the Caribbean
(b) to evaluate existing concept for suitability in the Caribbean context
(c) to design and evaluate new systems

Cost: U.S. $ 153,000

Period: 3 years

15) Title: Electric Energy Storage, and its Use in Electrically Driven Passenger Vehicles (Ref. [23])

Proposing organization: Commonwealth Science Council

Countries: Guyana, United Kingdom

Objectives: To utilize cheap electricity (at approximately G. 2 cents per Kv) produced within the sugar industry, in lieu of diesel oil to power passenger vehicles. In subsequent stages the concept could be extended to other forms of transport and farm vehicles.

Cost: not determined

Period: not determined

16) Title: Regional Programme on Solar Crop Driers for Use in Small Rural Communities in the Caribbean (Ref. [24])

Proposing organization: UNESCO

Countries: Trinidad and Tobago

Objectives: (a) Long-term objectives:

To develop low cost technology for the preservation of crops produced in the Caribbean using solar energy

(b) Short-term objectives:

(i) To identify crops which can be preserved by solar drying

(ii) To select different solar drying systems suitable for crops determined in (i) above

(iii) To operate suitable solar driers under field conditions in different localities and determine their economic and technical feasibility

Cost: U.S. $ 124,700

Period: 2 years

17) Title: Central American Energy Programme (Ref. [25])

Proposing organizations: U.N. Department of Technical Co-operation for Development, CEPAL, ICAITI, BCIE, COMENER

Countries: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua

Objectives: (a) Take advantage of the process of consolidation of National Energy Committees or equivalent organizations which are in charge of formulating and implementing national energy policies

(b) Technical assistance in the development of methods and instruments for planning of energy development and for rational utilization of the available energy resources in four of the five countries involved

(c) Organization and reinterpretation of existing information regarding petroleum exploration and technical assistance for continuation of activities of developing petroleum resources in various countries in the Region

(d) Technical assistance for the evaluation and development of geothermal energy

(e) Technical assistance for evaluation and development of non-conventional energy resources

(f) Training of technical personnel required for each sector

(g) Technical assistance to assure adequate legal and institutional infrastructure for each sector

(h) Identification and co-ordination of similar actions in the Central American countries in the energy sector in order to develop complementary utilization of energy resources at the regional level

(i) Complete a study of the electrical network in order to optimize electrical energy development in the Region

Cost: U.S. $ 509,000 (PNUD), 1,500,000 (OPEP)

Period: 3 years

18) Title: Study of the Potential of Solar Cooling for Food Preservation (Ref. [26])

Proposing organization: UNESCO; Energy Planning and Coordination Division, Ministry of Mining and Natural Resources; Energy Development and Demonstration Division, Scientific Research Council

Countries: Jamaica

Objectives: to study the possibility of using solar absorption cooling systems for food preservation and storage

Cost: not determined

Period: not determined

19) Title: Methane Generation from Animal Waste (Ref. [26])

Proposing organization: UNESCO; Energy Planning and Coordination Division, Ministry of Mining and Natural Resources; Energy Development and Demonstration Division, Scientific Research Council

Countries: not designated

Objectives: (a) To demonstrate the generation of methane by anaerobic fermentation of animal waste on -

(i) A farm of about 200 cows

(ii) A farm of about 600 pigs

(iii) A farm of about 5,000 chickens

(b) To demonstrate the use of methane so generated towards meeting the energy requirements of the farm whether for space or water heating, cooking, refrigeration, electricity generation or lighting, as appropriate

(c) To demonstrate the use of the residue from methane digesters as a fertilizer

(d) To provide training in the design, construction and operation of methane generators to appropriate personnel from Jamaica and the English-speaking Caribbean

(e) To assess the potential for the use of methane generators among the farming community in Jamaica

(f) To disseminate information and to stimulate public awareness and concern as to the importance of recovering energy from waste, and its contribution to efficient farming operations and to the national energy situation

Cost: U.S. $ 116,400

Period: 12-18 months.

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