Future Energy Sources

National Development Strategies

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Volume 3
Western Europe and North America

From McGraw-Hill, Publishers of
Coal Week ▪ Platt's Oilgrams ▪ Fuel Price Analysis

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Future Energy Sources: National Development Strategies

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Introduction

The world has consumed more commercial energy since 1940 than in all its previous history. Energy consumption will continue to rise, but energy sources will be diversified.

The finite nature of petroleum resources, increasing demand, and soaring prices have combined to force nations to look for new and renewable energy sources that will safeguard their futures. Economic, social and industrial development, as well as national security, is at stake. For developing countries, the stakes are especially high.

How nations are attempting to reduce their dependence on oil by developing alternate sources of energy is the subject of *Future Energy Sources: National Development Strategies*. This three-volume series is a compilation of reports detailing ongoing projects and development plans for renewable resources in 29 countries. The reports are edited and abridged versions of documents prepared by national governments for the United Nations Conference on New and Renewable Sources of Energy, held August 10-21, 1981 in Nairobi, Kenya.

Renewable energy sources discussed in these reports are: solar, geothermal, wind, hydro power, biomass, fuel wood and charcoal, oil shale and tar sands, ocean energy and peat. Most country reports focus on plans for developing the more universal energy sources -- solar, hydro power, biomass and geothermal energy. However for some areas, particularly Africa and the Mideast, great attention is paid to developing wood as the projected energy base.

Although the reports vary in length and detail, most assess present energy supply and demand patterns, and outline the methods that will be used to shift to secure, indigenous and renewable sources. They describe each country's policy for the transition and pinpoint individual energy development projects underway or on the drawing board.

In creating their national documents for the U.N. conference, governments were asked by U.N. officials to specify technologies of particular interest to their country; identify major constraints to their implementation; state means of overcoming the constraints; and outline the possible scope for international cooperation.

At the conference, 89 national documents were presented. McGraw-Hill energy editors carefully reviewed the documents, selecting for inclusion in the *Future Energy Sources* series the papers containing the most specific information about energy development plans.

In editing and preparing the materials, the editors clarified language and condensed reports where it was felt these changes were appropriate. For example, strictly geographic country descriptions, and the report chapters calling for international cooperation, were deleted or condensed if they overlapped other material or were already widely known. However, the substantive meaning of the papers was in no way altered. The information in the national papers was assumed to be accurate, and was not independently verified.

It should be noted that, because the papers were prepared by the various governments, certain political tones may be apparent in some. These do not reflect the opinions of either McGraw-Hill or the United Nations.

McGraw-Hill has grouped the reports geographically into three volumes. (The U.N. document numbers of the original documents are listed at the back of this book.) The volumes and countries covered in each are:

Volume 1: Mideast and Africa

Egypt, Israel, Jordan, Kenya, Liberia, Nigeria, Pakistan, Sierra Leone, Sudan and Turkey

Volume 2: Far East and the Soviet Union

Australia, Bangladesh, China, Indonesia, Japan, Sri Lanka, Thailand and the Soviet Union

Volume 3: Western Europe and North America

Austria, Canada, Denmark, France, Ireland, Italy, the Netherlands, Norway, Sweden, the United States and West Germany

Within each volume, reports are arranged alphabetically by country. To facilitate use, the volumes are indexed by energy source and a comprehensive Table of Contents appears for each country.

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(Editor's note: In this report, the European system of using commas rather than decimal points in numbers is used.)

INTRODUCTION

Austria is a small, industrialized country with some fossil energy resources and long tradition in the use of hydro power, which still provides about 70 percent of Austria's electricity supply. In the past, however, the significance of Austria's indigenous resource endowment has been steadily eroded. Twenty-five years ago, indigenous sources supplied some 80 percent of Austria's energy requirement, but today the share of net primary energy imports is of the order of 68 percent and is expected to increase by the end of this decade to about 75 percent.

These energy imports, mostly in the form of liquid hydrocarbons, impose a heavy burden on Austria's balance of payments and supply security. Thus, Austria's energy policy emphasizes the need for lessening the dependence on liquid hydrocarbons. To achieve this goal, a substantial effort in energy planning and research must be undertaken. This effort will have to focus on the:

- Optimal exploration and exploitation of indigenous energy resources.
- Efficient and rational use of energy.
- Identification of adequate substitutes for liquid hydrocarbons.
- Diversification of sources.
- Assessment of the potential contribution of new and renewable sources of energy.
- Development, testing and introduction of new, economically and environmentally sound energy technologies.

ENERGY SITUATION IN AUSTRIA

Table 1 contains figures on recent developments in the energy supply and consumption in Austria. From 1973 to 1980 the gross domestic energy supply rose by 5,5 percent, and the domestic primary energy supply decreased by 4 percent. However, imports of primary and secondary energy increased strongly (22,9 percent).

Table 2 further specifies the last column of Table 1. It outlines the changes in the patterns of final energy supply. The shares of gas, electricity, fuel wood and some other sources of energy increased, while those of liquid hydrocarbon-based fuels decreased. Also the heat supplied by district heating systems, included in "other" energy sources, has increased its share in the past years, although it is still rather small.

The conversion losses amounted to 106,8 PJ or 10,6 percent of the total energy supply in 1980. Deducing non-energetic uses and considering the changes in consumers' stocks, 761,0 PJ was consumed by final users for energy purposes (heating, process heat, mechanical energy, lighting and electro-mechanical processes) in 1980.

Table 3 indicates the use of energy by areas of consumption. The transport sector's share remained almost constant during the last years. Industry lost some percentage points, while residential and other small-scale users increased their shares.

Although the supplied quantities of domestic primary energy have remained more or less constant since 1973, their value has increased as the decrease in crude oil production has been more than offset by electricity generation from hydro power.

Energy Imports

In quantitative terms, net imports contributed to primary energy consumption at the rate of 20,5 percent in 1955 and 64,8 percent in 1973. Since 1973 this value has varied between 60,4 percent (1975) and 68,3 percent (1980).

In 1979, 69 percent of domestic electricity generation was supplied by hydro power and 31 percent by thermal power. Of the fuel consumed by thermal power plants, 45 percent was of domestic origin. In 1979, 17 percent of domestic electricity generation was based on imported fuels (coal, petroleum and gas).

Of Austria's total energy imports in 1979, 41,5 percent was supplied by OPEC countries (Iraq, Saudi Arabia, Libya, Algeria, Nigeria, Iran and Kuwait); 41,6 percent by CMEA countries (the Soviet Union, Poland, C.S.S.R., Hungary, East Germany and Romania); 12.8 percent by OECD countries (West Germany, Italy, the United States, Switzerland and France); and 3,1 percent by other countries (such as Yugoslavia and Egypt).

The value of energy imports (fossil fuels and electricity) amounted to about 25 billion Austrian Schillings AS (U.S. $1 equalled AS 17,20, as of June 1981) in 1978 and about AS 33 billion in 1979. The value of energy exports (mainly the balance of electricity exports and imports) amounted to AS 2,8 billion in 1978 and AS 3 billion in 1979. Net imports of fossil fuels and energy caused an energy trade deficit of AS 30 billion in 1979 and about AS 45 billion in 1980.

The deficit is largely the effect of increasing energy prices. In 1979, for instance, energy imports, quantitatively, were 29,5 percent higher than in 1972. Their value, however, had risen by 289,9 percent. In the same period, the energy trade deficit rose by 347,7 percent, from AS 6,78 billion to AS 30,35 billion.

Energy Consumption Forecasts

According to the energy consumption forecast of the Austrian Institute for Economic Research (Institut fur Wirtschaftsforschung, WIFO) in April 1980, annual growth rates of 2,7 percent must be expected until 1985, and of 2,2 percent from 1986 to 1990.

The forecast does not project an increased fuel oil consumption after 1985. Petrol consumption will rise by 2,4 percent annually until 1985, and from then to 1990 by 1,5 percent annually. The annual growth rates of electricity consumption are projected to be 4,6 percent until 1985, and 3,6 percent from 1985 to 1990 (see Table 4).

Total energy consumption is forecast to reach about 1158 PJ in 1985 and 1294 PJ in 1990. The share of liquid hydrocarbons is projected to decrease by 3,6 percent, the share of hydro power to increase by 4,2 percent. Higher shares are expected for coal and gas (see Table 5).

Although efforts are being intensified to develop methods for the use of waste heat from thermal power plants (co-generation systems) and from industrial processes, significant progress is not expected until after 1990. District heating systems will provide 2,3 percent of final demand in 1985 and 2,8 percent in 1990 (from 1,7 percent in 1978).

The use of new and renewable sources of energy is expected to increase in Austria, in particular with regard to hydro power, and to some extent with regard to biomass and solar energy. The constraints for the large-scale use of biomass, solar, wind and geothermal energy have not yet been examined enough in detail and technologies not yet sufficiently tested to assess their potential. As a result of intensified research, development and demonstration activities, renewable sources of energy might, in the long run, be able to contribute on a broader scale to the Austrian energy supply. Until 1990, solar and heat pump systems as well as geothermal energy sources could, at the most, substitute hydrocarbons by 1 to 2 percent.

HYDRO POWER

Hydro power actually supplies 70 percent of the Austrian electricity consumption. The hydro power potential of 44 domestic river systems is compiled in the Austrian Hydro Power Register (Wasserkraftkataster). The exploitable potential is assessed to be, as of 31 December 1978, 49.246 GWh per year for a standard year. By 1995, the plants already in operation as well as those still under construction or in design will use 85 percent of the exploitable hydro power potential. By that time, 96 percent of the potential applicable for basic load supply will have been developed.

The larger part of the hydro power potential not yet developed consists of smaller rivers. Compared with other alternatives ecological, hydrological and regional planning considerations usually support the building of small hydro power plants (with initial outputs of less than 5 MW).

The degree of exploitation of the small-scale hydro power potential also depends on such factors as the balance of energy supply and demand, the effectiveness of investments required, private initiative and the measures introduced for the protection of the environment.

Summing up, Austria's exploitable small-scale hydro power is assessed at 3.000

to 4.000 GWh per year, corresponding to 8 to 11 percent of its electricity consumption in 1979.

At present, about 1.300 small hydro power plants are operated in Austria with a capacity of 370 MW. This corresponds to an annual energy production of about 2000 GWh.

Large-scale storage power plants often represent a particular challenge to construction engineering. Latest technological developments make the construction of high dams technically as well as economically feasible.

Owing to their broad environmental impact, large storage systems can serve various purposes simultaneously. By their construction, the water discharge in winter will be offset in other seasons. The construction works themselves may advance the improvement of regional infrastructures which can stimulate other activities, such as tourism.

Present research concentrates on three main areas: small-scale hydro energy potential assessment, improvement of existing plants and development of hydro power technology.

BIOMASS

An estimated 200 PJ per year could be produced from biomass (wood, straw, animal dung) in Austria. Research is being done on methods actually used and on new technologies. Energy might be derived from energy farming, in particular on soils with marginal yields.

To determine the use of biomass for energy production in Austria, studies were completed on the availability of areas for the production of biomass and on related energy input/output balances.

Energy from biomass is mostly supplied in a decentralized mode to meet local demand. Agriculture and forestry are not only the main suppliers of biomass, they also manage its conversion into useful energy.

Biomass usually is scattered over large areas. Its harvesting and transport are usually difficult and have not yet been sufficiently examined. Cost-effective and energy-saving transportation is essential.

At present, biomass is used in individual stoves and industrial boiler plants. The use of biomass as a primary energy source may be considered for commercial or industrial plants in a co-generation mode. In many cases, the cost of transport is the main economic obstacle to using biomass in centralized energy supply. Therefore, the conversion of wood into gaseous or liquid fuels (methanol, wood and gas) is being studied and tested in pilot plants. A number of such processes already have been developed (such as automatic burning systems, anaerobic fermentation of starch and sugar into power alcohol that can be used as fuel, or wood gasification).

The energy yield from a given quantity of biomass depends to a large extent on the energy input for its production, harvesting and transportation. Intensive exploitation, increase of the yield (by fertilization, irrigation etc.), mechanization of harvesting and transport can improve the ratio between energy input and output (conversion factor). In the case of combustion, the ratio can be in the order of 4:1. In the case of methanol production from wood, without co-generation, the ratio is 1,28:1 at the present state of technology.

Forest Biomass

Wood has the largest potential of all types of biomass available in Austria. Fuel wood provides 4,0 percent of the final energy consumption in the country. It is used nearly exclusively for small-scale residential space heating.

The theoretically exploitable forest biomass is estimated at 27.5 million cubic meters per year, of which 19 million cubic meters are hardwood, 2,8 million cubic meters are stump and root wood and about 5,7 million cubic meters are logging residues. However, only about 13,1 million cubic meters annually would be available for use as fuel wood, equivalent to a gross energy output of 70,6 PJ (about 8,1 percent of Austria's energy supply).

Only 65 percent of the tree mass is used at present. Of the tree components remaining in the woods, 2,2 million cubic meters is residues (branches and brush wood), 0,7 million cubic meters is needles, 3,1 million cubic meters is stump and root wood and 0,5 million cubic meters is bark.

If all reserves were exploited at maximum, forest biomass theoretically could countribute 148,7 PJ (gross energy) per year or 17,1 percent of Austria's energy consumption in 1975.

Massive exploitation of forest biomass (wood, bark, branches, brush wood and needles) may require additional fertilization under certain conditions. Moreover, the extraction of roots from slopes could cause dangerous soil erosion.

There remains about 2,7 million cubic meters of chopped wood. Realistically, 1 million cubic meters (about 8 PJ) could be used per annum.

The larger part of wood used in Austria for industrial purposes is processed by milling, cellulose, paper and panel industries. The economic importance of wood-based industries limits the use of wood for energy production. However, by substituting waste paper for wood as raw material for the production of paper and cardboard, about 250.000 cubic meters of wood with an energy potential of 2 PJ could be used for energy production.

Other measures, such as optimal choice of trees, shortening crop rotation cycles and additional fertilization might contribute to a quantitative increase of up to 80 percent by 2000. The cultivation of additional energy forests could provide 20 million cubic meters of firewood per year or 150 PJ per year.

Straw

Straw also should be considered a source of energy for heat and even electricity production. Only small amounts are used in the building and chemical industries. In Austria's grain-growing areas, straw is frequently considered a waste product, often burnt on the fields. Straw has a calorific value of about 15 MJ per kilogram, one-third of the calorific value of fuel oil. It requires 10 times the transportation volume of fuel oil. Its advantage, however, is a sulfur content of 0,05 percent, which is much lower than that of coal and oil.

About 3,5 million tons of straw (about 53 PJ per year) are available in Austria annually.

In rural areas, if only short transportation is required, straw is the cheapest fuel. It is used for heating purposes in hundreds of small facilities. The burning of straw in larger heating furnaces presents technical problems (at higher temperatures silicate is formed in the furnaces).

Grape Marc

Grape marc is another type of biomass suitable for energy production. Moreover, its end product is also a substitute for chemical fertilizers. It is estimated that 80.000 tons of wet grape marc become available in Austria annually. In the process of anaerobic fermentation of 1 kilogram of press residues (dry marc), 20.000 kJ is released.

The use of grape marc for heat production is being tested in pilot plants.

Wastes

Animal dung and the sludge of municipal sewage treatment plants contain an energy potential of 24 PJ per year. This potential could be used through biogas technology. Although this technology has been known for a long time, technical problems arising have not yet been solved and limit its large-scale application. Studies are being undertaken to determine the use of residues for the production of high-quality fertilizers.

Bio-Fuel (Power Alcohol)

Recent energy developments have led to the discussion of an Austrian power alcohol program. The study of alternative fuels or additives to conventional fuels must focus on the:

- Availability of raw materials and technologies.
- Applicability in conventional engines and possible substitution of conventional fuels.
- Economic efficiency of production and distribution.

The implementation of a power alcohol program could enhance the economic potential of certain regions in agriculture and related sectors.

The economic production of bio-fuels requires the cultivation of suitable plants with high sugar contents and high yields. In Austria, sweet sorghum and sugar beet appear to be adequate for this purpose. Calculations have shown that the energy balance of ethanol production from biogenous feedstocks is positive, in particular if waste products are used as animal fodder and/or fertilizer.

By adding ethanol to petrol, the carbon monoxide content of exhaust gases can be reduced by 20 to 25 percent.

SOLAR ENERGY

In Austria the insolation values vary as follows: March to May 450 KWh per square meter; June to August 520 KWh per square meter; September to November

250 KWh per square meter; December to February up to 160 KWh per square meter. The annual global radiation sum is of the order of 1400 KWh per square meter.

The unfavorable ratio of maximum (June) and minimum (December) irradiation in Austria is obvious. Ratios of 8:1 are possible. In the case of certain applications, such as space heating, energy demand is highest when supply is lowest.

The daily sums of insolation on cloudless days in summer may be as high as 8 KWh per square meter.

A large amount of heat is stored, although at temperatures below the level needed for practical use, in the environment (ambient heat). The soil temperature 2 meters below surface is $4^{o}C$ to $12^{o}C$; the temperature of surface water (rivers and lakes) may reach $20^{o}C$. Groundwater has a more or less constant temperature of $8^{o}C$ to $12^{o}C$ throughout the year. The temperature of the air varies, of course, more strongly (mean daily temperatures at 200 meters altitude between $-8^{o}C$ and $+20^{o}C$).

Heat Production

Solar energy can be used for the production of low-temperature heat (up to $50^{o}C$) by:

- Direct conversion of solar energy into heat through collectors -- solar systems.
- Utilization of the solar energy stored in the environment in the form of ambient heat by means of heat pumps -- heat pump systems.

Under Austrian meteorological conditions the flat-plate collector is applicable because it also can absorb diffuse radiation. To improve the thermal efficiency by reducing heat losses due to thermal radiation and convection, transparent covers (glass or plastic) are placed on the collectors.

Collectors with transparent covers can be used for residential water heating throughout the year. During the summer months, even plastic collectors can be used.

In combination with heat pumps, non-covered collectors can use other sources of environmental energy, such as the latent heat contained in the condensation water of the air. Accordingly, those collectors perform the additional function of heat exchangers for energy sources contained in the air, and they most likely can be successfully used in conjunction with heat pump systems.

At present, solar systems in Austria are used mainly for residential water heating as well as for swimming pool heating and the combination thereof. In the case of space heating by means of solar and/or heat pump systems, high demands are placed upon the heat insulation of the building and the heat distribution system (low-temperature heating system). Several concepts are being tested, with special attention given to their cost-effectiveness.

The thermal energy output of a solar system depends to a large extent on insolation, ambient air temperature and the working temperature of the collector system. The latter always will be kept as low as possible -- in the case of a swimming pool below $30^{o}C$ and in the case of residential water heating below $50^{o}C$.

Under these conditions, about 25 to 30 percent of incident solar energy can be converted into useful energy. Thus about 300 to 350 KWh of the total incident radiation of 900 to 1.400 KWh per square meter of collector area a year can be used in the form of low-temperature heat (300 to 350 KWh per square meter annually). These figures are confirmed by measurements taken at Austrian solar energy test stations operated on behalf of the Austrian Federal Ministry for Science and Research.

The conventional energy savings resulting from the use of solar heating systems can be determined by the so-called energy analysis where all energy inputs and outputs are calculated. Energy input comprises the energy needed for the manufacture of the equipment and the plant itself, as well as the energy required for transport. Energy output (low-temperature heat) depends on the thermal efficiency of a collector, which, in turn, can be determined by using the conversion factor and the heat loss factor of a collector. The energetic amortization period for a solar collector manufactured and used in Austria is calculated at two to four years.

The heat pump makes use of the heat stored in the environment (groundwater, air and soil) and of various waste waters. Its use reduces the primary energy requirements for heat production and lessens the dependence on liquid hydrocarbons.

High-quality energy (electricity, diesel fuel and natural gas) is required for the operation of heat pumps. The conservation of primary energy by using heat pumps for heat production depends on:

- Conversion losses in the process of the production of energy required for the operation of the heat pump (electricity, diesel fuel and natural gas).

- The coefficient of performance (COP) of the heat pump.

The COP (which has to be higher than 1) will determine the energy saved by an electrically operated heat pump compared to electric heating (direct heating or boiler heating). If compared to an oil- and gas-fired central heating system, the COP would have to be at least 2. The average COP of heat pumps is of the order of 2,3 to 3,3. The fact that in Austria part of the electricity is generated by hydro power plants even during the winter months facilitates the saving of primary energy by using electrically operated heat pumps.

Gas- or diesel oil-operated heat pumps can save even more primary energy than electrically operated heat pumps because they can utilize the energy contained in the cooling water of the engine and in the exhaust heat.

The application of heat pumps for space heating is being examined both in demonstrations and practice. Only in particularly favorable cases will it be possible to use groundwater as a source of heat, especially because possible negative effects on the recovery of drinking water have to be taken into account. In Austria, the use of ground or surface water requires official authorization.

For heat pumps the loamy, hydrous soil is a good heat-extraction medium. It can be heated up, if necessary (in layers more than 2 meters below the surface), by solar collectors or waste heat from space and residential water heating.

The use of solar and heat pump systems is increasing in Austria. Until the end of 1980, about 64.000 square meters of collector area were installed, 62 percent for residential water heating, 18 percent for swimming pool heating and 18 percent in combined systems (residential water and swimming pool heating). At present, only about 2 percent of the solar systems are used for space heating.

By the end of 1980, 5.800 electrically operated heat pump systems were in operation, 73 percent of which with a thermal power capacity of up to 15 KW. Gas or diesel-operated heat pumps with capacities of more than 50 KW are only used in pilot systems.

Some figures may illustrate the increasing manufacturing capacity of the Austrian solar industry. At present, about 56.900 square meters of collector area is produced in Austria annually, 64 percent of which is exported. In 1980, 8.100 heat pumps were manufactured.

Solar systems for the production of low-temperature heat use solar energy directly -- solar energy is converted into heat in the collector and from there supplied to the consumer. Heat pumps, in contrast, use solar heat stored in the environment which is re-heated by solar energy. Thus, the use of solar energy and ambient heat can reduce the demand for commercial energy, in particular in the area of space heating. Furthermore, solar energy can be used by the introduction of passive solar systems.

It is estimated that 3 to 5 percent of total primary energy demand in Austria can be saved up to the year 2000, if the application of solar and heat pump technologies further increases. Statistically, the reduced consumption of commercial energy is indicative of the contribution of solar energy (including passive solar energy systems and the use of ambient heat) to the energy supply.

Electricity Generation

In view of the particular geographical and meteorological conditions prevailing in the Alpine regions, studies have been undertaken to examine the feasibility of installing combined solar-hydraulic systems for electricity generation in Austria. The areas required for the large-scale utilization of solar thermal power plants are available in Austria, mostly outside agricultural production areas. However, adequate high altitude locations with good meteorological conditions, particularly in winter, are limited in number. There are about 16 locations with a potential of 800 MW.

In Austria, solar thermal power plants could operate only 1.100 hours per year (conventional power plants: 4.000 to 6.000 hours per year).

For thermal and economic reasons, solar thermal power plants designed for centralized energy supply need to be in the megawatt range. Capital requirements are high; it is, therefore, essential to carry out comprehensive studies regarding the entire system as well as the sub-systems and the components in relation to specific sites.

A heliostat for the Central Receiver System (CRS) has been developed with special attention to the meteorological conditions in the Alpine regions, and it is now being tested.

Research is also being undertaken in Austria on the development and testing of photovoltaic systems, using silicon, cadmium sulfide or cadmium telluride solar cells. Technologies for the manufacture of thin layers are considered to be of particular importance.

Economic electricity generation by solar thermal or solar electric power plants is not expected before the year 2000 in Austria.

WIND ENERGY

Wind energy has already been sporadically used for electricity generation, especially in remote areas not connected to the national grid.

The technical wind energy potential in Austria is estimated at about 40 TWh per year. Only areas with wind velocities above 5 meters per second occurring with the required frequency are considered for exploitation.

The development of wind energy systems in Austria concentrates on nominal capacity ranges less than 150 KW which can be subdivided as follows:

- Minimum-capacity units (less than 10 KW).
- Low-capacity units (up to 30 KW).
- Medium-capacity units (up to 150 KW).

Two types of systems are being developed -- the high-capacity propeller system (with two blades) and the Darrieux system (with two blades).

The systems have the following characteristics:

- Simple systems for local construction in countries with weak capability in energy technology.
- Optimized high capacity units of high technology requiring little maintenance, suited for countries with sufficient service structure. These devices are designed in particular for use in areas connected to the national grid. They can be used for heating and for pumps as well as for frequency-stabilized electricity generation.

Combinations of wind energy systems with solar, heat pump and conventional energy supply systems appear to be of particular interest.

Measurements have shown that the correct choice of tower height is of particular importance. Choosing the wrong height may cause efficiency losses. For rapid determination of the gradient at the planned site, a transportable measurement tower is being developed.

Equipment and devices ready for commercialization will cost in the range of AS 12.000 per installed kilowatt. Such facilities can be amortized in areas with a wind velocity of 7 to 8 meters per second within two to six years, in areas with an average of 9 to 11 meters per second even sooner.

Already today, wind energy units installed in remote areas are operating economically.

GEOTHERMAL ENERGY

In Austria, geological conditions for geothermal anomalies exist in very limited areas only, such as in the basin of South Styria, in Burgenland, in the molasse areas of Upper Austria, Salzburg and the Rhine valley in Vorarlberg. Their utilization is being examined in pilot facilities.

According to the present state of geological knowledge, no steam from geothermal sources can be expected in Austria. Also hot and dry rock can be located in Austria in great depths only. Prohibitive costs hamper their utilization.

As it stands today, no major contribution is expected from this source to the Austrian energy supply.

ENERGY POLICY AND RESEARCH

The Institutional System

Austria is a federal state. The federal government (Bund) and the federal provinces (Lander), within their respective fields of competence, are responsible for energy matters including research and development.

At the federal level, federal ministries are responsible for energy matters, including research and development, with respect to their specific areas of activity.

Matters of energy policy are handled by the Federal Ministry for Trade, Commerce and Industry.

The responsibility for the coordination of energy research and development at the federal level rests with the Federal Ministry for Science and Research.

By a federal law enacted by Parliament in 1979 the federal government is obliged to submit to the Austrian National Assembly (Nationalrat) a comprehensive annual report on energy policy (Energiebericht der Bundesregierung) as well as a report on the state-of-the-art and on the objectives of research and development in Austria (Osterreichischer Forschungsbericht).

Goals and Principles of Energy Policy

To secure Austria's energy supply and to minimize negative impacts on the economy and on the environment, the energy policy and research in Austria are aimed at:

- Optimizing the exploration for and the use of domestic resources of energy, in particular by further exploitation of hydro power, and new sources of energy or those rarely used up to now, such as biomass, solar and geothermal energy.
- Substituting hydrocarbons as far as possible.
- Reducing energy consumption through more efficient energy use.
- Securing the necessary energy imports by diversifying supplier countries and energy sources.

The energy policy of the federal government emphasizes the exploration for oil, natural gas and coal deposits, and in particular the expansion of both large-and small-scale hydro power. The power plant expansion program provides for the continuous expansion of hydro power. Besides the construction of large- and medium-size plants, particular attention is given to the expansion of small hydro power plants. As such small plants have considerable potential for future energy supply, a number of measures have been taken for their promotion, such as tax reductions, loans and interest allowances.

These and other actions are part of the package of measures approved by the federal government in July 1979 and supplemented by a timetable. Later a comprehensive and further improved catalogue of measures was published in the 1980 federal government report on energy policy and adopted by the Austrian National Assembly.

Goals and Principles of Energy Research

The objective of the Austrian Concept of Energy Research is to ensure that work sponsored from public funds is in conformity with the goals of Austria's energy policy and takes into consideration concerns of the economic and research policy, including environmental factors. Austria's Concept of Energy Research was first established in 1974 and is being updated periodically.

As founding member of the International Energy Agency (IEA), Austria has accepted responsibility for promoting energy policy and research in accordance with other IEA member countries. Austria's Concept of Energy Research was reviewed in 1980 in the light of the energy research, development and demonstration strategies presented by the IEA in early 1980.

The federal ministries have continuously increased their expenditures for energy research; in 1975, these amounted to AS 10,0 million, in 1980 to AS 74,4 million.

The federal funding (federal ministries, universities, research institutes and research promotion funds) for energy research projects came to AS 374,5 million in 1980.

The Industrial Research Promotion Fund has increased its allocations for energy research in industry from AS 38,35 million in 1977 to AS 114,10 million in 1980. In addition, industry used AS 222,17 million of its research budget for energy in 1980.

In addition to financial support, appropriate legislative measures often are required to accomplish the objectives of research programs.

The exploration and use of new and renewable sources of energy may create some new legal problems as well. From the point of view of civil and public law, a recently conducted study examined controversial situations arising in connection with the application of commercialized solar and wind energy devices. Possible solutions were elaborated and proposals for new regulations made.

Special Measures for the Promotion of Solar and Heat Pump Technologies

If their application meets specific energy policy requirements, solar and heat pump systems qualify for tax advantages as energy saving investments.

Even under the meteorological conditions of Austria, appropriately designed solar and heat pump systems can reduce the demand for conventional energy (including oil, gas, coal and electricity). This has been demonstrated by examination of selected plants and by the experience gained since 1974 with solar and heat pump systems operated within the framework of the Austrian Measuring Network for the Practical Use of Solar Energy.

Standards for solar collectors and heat pumps already are available in Austria. Guidelines and recommendations for planning, design and operation of solar and heat pump systems have been elaborated by the Austrian Solar and Space Agency (ASSA) based on results gained with existing facilities.

Reliability, cost-effectiveness, serial production of parts and components, and better information on technologies are preconditions of using new and renewable sources of energy. Appropriate documentation, teaching and demonstration materials have been elaborated in Austria, in order to provide information to all interested and to promote the use of solar systems, heat pumps and similar systems.

The introduction of new technologies requires good training of technical manpower. For this purpose, seminars are held at regular intervals, dealing with the planning, design and operation of solar and heat pump systems. Between 1977 and 1980, more than 130 seminars were held in Austria on this subject.

TABLE 1. ENERGY SUPPLY AND CONSUMPTION 1973-1980

Year	Supply: Domestic primary energy	Supply: Imports of primary and secondary energy	Supply: Total [1])	Consumption: Conversion Input	Consumption: Conversion Output	Consumption: Supply to end users [2])
	in PJ (1 PJ = 10^{15} J)					
1973	357,536	587,127	903,658	735,085	591,289	703,039
1974	356,050	573,868	891,378	713,908	575,714	696,014
1975	354,691	533,500	867,269	689,740	548,208	668,911
1976	325,180	631,378	905,112	736,351	591,526	711,210
1977	347,271	605,843	872,681	706,610	594,071	695,057
1978	352,535	665,713	906,501	751,455	639,973	718,271
1979	361,426	711,375	947,817	799,480	689,766	765,748
1980	343,383	721,510	943,398	790,609	683,848	761,075

[1]) Domestic gross energy supply after deduction of energy exports and consumption as well as losses and changes in the stocks of energy producers.
[2]) After deduction of non-energetic consumption and taking into consideration the recorded changes in the stocks of energy consumers.

TABLE 2. ENERGY SUPPLIED TO FINAL USERS BY ENERGY SOURCES 1973-1980
(in %)

Year	Solid mineral fuels	Liquid petroleum-based fuels	Gaseous fuels	Electrical energy	Firewood	Other energy sources
1973	13,58	54,49	13,27	13,25	3,68	1,73
1974	14,10	51,86	14,96	13,95	3,56	1,57
1975	13,19	52,43	14,56	14,31	3,69	1,82
1976	12,54	51,00	16,48	14,59	3,52	1,87
1977	11,64	52,18	15,19	15,44	3,66	1,89
1978	11,12	50,89	16,09	15,58	4,15	2,17
1979	12,36	50,57	15,32	15,03	3,68	3,04
1980	11,86	49,26	16,17	15,70	3,90	3,11

TABLE 3. ENERGY CONSUMPTION BY ECONOMIC SECTORS
(in %)

Area of consumption	1977	1978	1979
Transport	24,4	23,5	24,0
Residential uses	24,9	26,0	41,7
Other small-scale uses	12,9	13,0	
Industry	37,8	37,5	34,3
Consumption by final users	100,0	100,0	100,0

TABLE 4. GROWTH RATES OF ENERGY CONSUMPTION

Area of consumption	1978/1985	1985/1990
	Annual changes in %	
Total energy consumption	+ 2,7	+ 2,2
Energy consumed by final users	+ 2,9	+ 2,2
Conversion	+ 2,8	+ 1,7
Industry	+ 2,3	+ 1,5
Transport	+ 2,4	+ 1,5
Small consumers (residential and other small-scale uses)	+ 3,5	+ 3,0
Consumption		
Fuel oil (including gas oil for heating purposes)	+ 3,0	0,0
Petrol	+ 2,4	+ 1,5
Electricity	+ 4,6	+ 3,6

(Austrian Institute for Economic Research, April 1980)

TABLE 5. PATTERNS OF PRIMARY ENERGY CONSUMPTION*

Sources of energy	1976	1978	1985	1990
	Actual		Forecast	
	in PJ			
Coal	163,160	139,567	195,151	204,054
Oil	476,364	500,341	597,233	618,162
Gas	172,483	182,617	190,413	261,818
Other energy sources	30,246	32,050	34,564	36,870
Hydropower	85,121	102,839	140,799	172,929
TOTAL	927,375	957,414	1.158,160	1 293,833
	Shares in %			
Coal	17,6	14,6	16,8	15,8
Oil	51,4	52,3	51,7	47,8
Gas	18,6	19,1	16,4	20,2
Other energy sources	3,2	3,3	3,0	2,8
Hydropower	9,2	10,7	12,1	13,4
TOTAL	100,0	100,0	100,0	100,0

(Austrian Institute for Economic Research, April 1980)

*) Indigenous production plus import minus stock changes (producers' and consumers' — if available) minus export.

TABLE 6. ANNUAL PRODUCTION OF FOREST BIOMASS, QUANTITIES THEORETICALLY AVAILABLE FOR ENERGY PRODUCTION AND SHARE IN AUSTRIA'S ENERGY CONSUMPTION OF 1975 (ESTIMATES)

Form of bio-mass*	Annual production	Quantities theoretically available for energy production	Gross energy	Potential share in Austria's energy consumption of 1975
	in million cubic meters		in PJ	in %
1	13,3	1,4	7,56	0,87
2	1,3	1,0	5,40	0,62
3	3,1	3,1	16,56	1,91
4	5,7	4,0	21,60	2,49
5	2,8	2,0	10,80	1,24
6	2,6	1,6	8,64	1,00
		13,1	70,56	8,13

*) 1 hardwood logged per year, 2 = portion of bark of the wood logged per year, 3 = portion of branches, brushwood and needles of the wood logged per year, 4 = softwood reserve (bark), 5 = stump- and rootwood utilized per year, 6 = portion of branches, brushwood and needles of the softwood reserve.

TABLE 7. SOLAR AND HEAT PUMP SYSTEMS IN AUSTRIA

SOLAR SYSTEMS

COLLECTOR PRODUCTION	56.900 m²	(1980)
EXPORT	36.400 m²	(1980)
IMPORT	2.600 m²	(1980)

INSTALLED SOLAR SYSTEMS 1980	AUSTRIA	EXPORT
DOMESTIC WATER HEATING (DH)	850	1.970
SWIMMING POOL HEATING (SH)	240	530
COMBINATION SH + DH	250	530
SPACE HEATING	30	—
TOTAL	1.370	3.030

INSTALLED COLLECTOR AREA IN AUSTRIA

YEAR	1975	1976	1977	1978	1979	1980
m²/year	100	2 200	3 500	7.000	27.800	23.100
TOTAL m²	100	2 300	5.800	12 800	40.600	63.700

APPLICATIONS	1975 — 1979	1980
DOMESTIC WATER HEATING (DH)	43%	62%
SWIMMING-POOL HEATING (SH)	36%	18%
COMBINATION SH + DH	18%	18%
SPACE HEATING	3%	2%

DISTRIBUTION OF SYSTEMS BY COLLECTOR AREA

	1975 — 1979	1980
< 10 m²	24%	48%
10 to 30 m²	57%	32%
30 to 70 m²	13%	13%
> 70 m²	6%	7%

HEAT PUMP SYSTEMS

HEAT PUMP PRODUCTION (1980)	8 100
EXPORT	3.500 (43%)

INSTALLED HEAT PUMP-SYSTEMS

	1975	1976	1977	1978	1979	1980
YEAR	10	30	60	300	800	4.600
TOTAL	10	40	100	400	1.200	5.800

APPLICATIONS:	
DOMESTIC WATER HEATING	55%
SWIMMING-POOL HEATING	5%
SPACE HEATING	30%
COMBINATION	10%

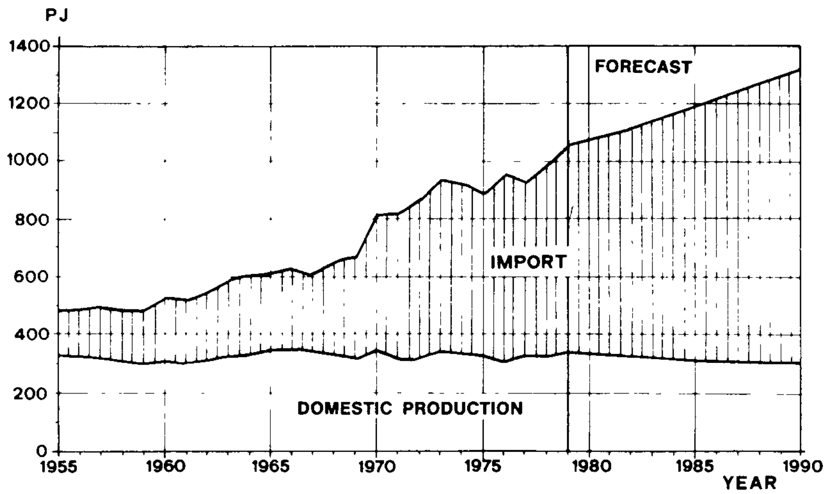
DISTRIBUTION OF SYSTEMS BY HEAT SOURCES

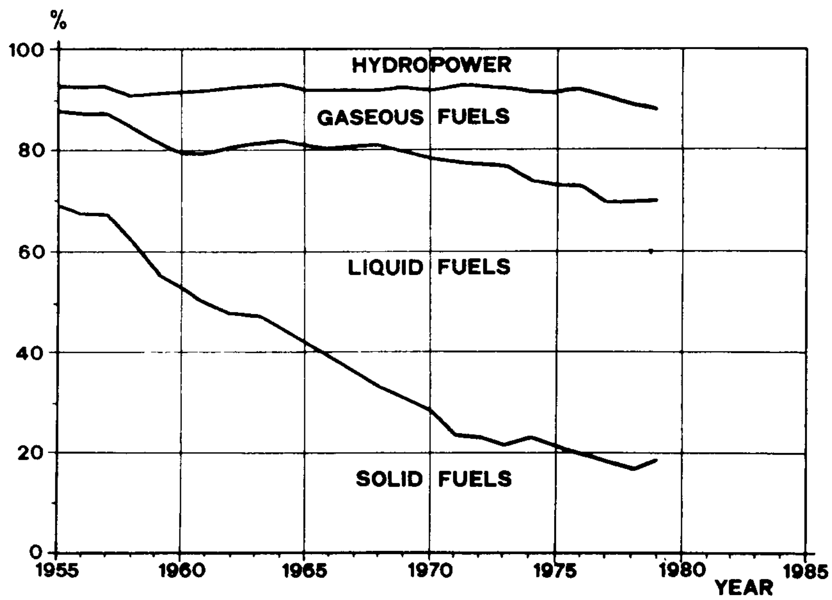
AIR	80%
WATER	19%
GROUND	1%

DISTRIBUTION OF SYSTEMS BY THERMAL POWER OUTPUT

< 3 kW	3 — 7 kW	7 — 15 kW	15 — 30 kW	> 30 kW
42%	13%	21%	17%	7%

FIGURE 1. ENERGY SITUATION IN AUSTRIA: ENERGY SUPPLY AND ENERGY SOURCES





Canada

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INTRODUCTION

Canada, compared to most countries, is well endowed with energy resources. It is, in fact, a net exporter of energy. However, it is in no sense insulated from the energy concerns which affect the rest of the world because, like most countries, Canada imports oil. About 43 percent of Canada's primary energy consumption is oil, of which one-quarter (gross) is imported. Net imports of oil currently are about 140,000 barrels per day.

Prior to the international oil price increases and availability problems of 1979-1980, this import dependence was expected to grow as domestic production from conventional oil reserves fell, with net imports reaching some 600,000 barrels a day by the mid-1980s. This would be counterbalanced by increasing exports of natural gas, electricity and coal.

Canadian energy policy now centers on the reduction of this import dependence through the development of indigenous resources (natural gas, coal, nuclear fuels, unconventional oil and renewable energy), substitution of other energy forms, including renewables and wastes, for oil consumption wherever possible, and reduction of demand through improved efficiency and conservation. The overall aim is to eliminate oil imports by 1990, reducing oil consumption to only 10 percent of energy demand in each of the economic sectors, with the exception of transportation. Oil will then represent 27 percent of total consumption, rather than the present 43 percent. Many new programs of incentives and regulation are being put in place to achieve these objectives by both federal and provincial governments, including a number concerning new and renewable energy. Conventional hydroelectric generation currently supplies more than 60 percent of Canada's electricity (about 24 percent of its total primary energy). With this exception, renewable energy is not expected to make contribution in the next decade. However, it is seen as the key to a stable long-term energy future. Government programs are encouraging this long-term development of renewable and alternative energy with research and development assistance, demonstrations, industrial support and market stimulation. As the prices of other forms are allowed to rise, the economic competitiveness of various renewable applications will continue to improve.

In terms of its energy consumption, Canada is also in many ways a unique country. It is one of the highest users of energy per capita in the world due in part to its climate, long transportation distances and dispersed population, and its energy-intensive industrial structure based on its indigeneous natural resources. Canadian patterns of energy use are changing to incorporate conservation and substitution, and expertise is being developed in areas of special concern to Canada, such as conservation in the forest-based industries and new sources of fluid fuels. In the near term, and probably to the end of this century, conservation is likely to play a bigger role than most renewable energy sources in contributing to energy self-sufficiency in Canada.

The diversified resource base and the geographic and social structure of the country have ensured the development of special Canadian expertise in many specialized aspects of new and renewable resource production and use. Transfer of this experience constitutes the main contribution Canada can make to the developing countries. For example, Canada has experience and expertise in such areas as energy planning and systems development, engineering and design for unique applications, transmission and transportation techniques, remote community applications, development of hydro resources, forest management and use of biomass in forest industries.

In Canada, the energy scene is complicated by the balance of powers between federal and provincial governments. The provinces have ownership and control of resources within their borders, and also have jurisdiction over many of the activities involving energy demand. They make a substantial contribution to the funding of research and development associated with energy projects. The ubiquitous and non-depletable nature of most renewable energy sources means that both levels of government can be, and are, involved in the encouragement of their promotion and exploitation, often with overlapping or joint activities. Many provinces, such as British Columbia, are just now establishing the details of a renewable energy strategy which will cover the elements of resource assessment, development and demonstration, followed by eventual commercialization of appropriate technologies. Others, such as Quebec (as early as 1978), have established a renewable energy strategy and are implementing policies promoting the development and the use of new and renewable energy sources.

However, in cases where resources are localized in specific areas of the country, policies may differ in perspective among provincial governments and between federal and provincial governments. At the present time, for example, discussions and negotiations are continuing between the federal and western provincial governments on revenue distribution and other issues related to tar sands development, and the final outcomes in terms of resource availability and pricing are still unclear.

NEW AND RENEWABLE ENERGY IN CANADA

Canadian government interest in renewable energy was demonstrated in 1974 with the establishment of a program of renewable energy research and development. A further major initiative in 1978 launched several new programs oriented toward industrial development in the area. More recently, the 1980 National Energy Program emphasized the future role of renewable energy sources in providing for a stable and independent future. The following passage from the National Energy Program illustrates this perspective:

"Canada is well endowed with nonrenewable resources that

> can provide a bridge into a future where Canadians use less energy in their daily lives, and renewable energy plays a much larger role. Renewable energy in the form of hydroelectricity already contributed 24 percent of Canada's energy. Other renewables contribute a share approximately equal to that of nuclear power... The realities of the energy future indicate the wisdom of accelerated efforts to develop new and renewable energy forms, to stand beside hydroelectricity as the basis for a sustained, clean, and economically viable energy structure.
>
> The National Energy Program envisages a much greater role for renewable energy. The government of Canada believes that economic realities now favor a range of renewable energy options. The National Energy Program will provide further incentives to the commercial use of these resources, both within the comprehensive off-oil effort already described, and in the form of special new or enriched programs. It will also provide increased funds for research, development and demonstration of renewable energy."

This encouragement of renewable energy options, and conservation is echoed also in the policies of most of the provincial governments of Canada, and jointly funded demonstration projects exist across the country.

Currently, aside from the supply of conventional (large-scale) hydroelectricity, renewable energy supplies about 3 to 3.5 percent of Canada's total energy needs -- almost entirely from biomass. Under the National Energy Program, this contribution should double by the year 1990 to about 6 percent, and triple by the end of the century, with a large proportion from biomass. (The true size of the renewable energy contribution is difficult to assess because a great deal does not enter conventional markets and thus is excluded from energy statistics.)

The most important provision of the National Energy Program specific to renewable energy is the establishment of Canertech, a new Canadian alternative energy corporation, restricted to renewable energy and conservation technology. This crown corporation, with initial funding of $20 million, will focus on supporting commercial production of these technologies, and reinforcing the work of Canadian businesses in this field by joint ventures, equity investments and other assistance. It also may carry out research, development and demonstration.

In addition, the off-oil incentives of the energy program (the Canadian Oil Substitution Program) are neutral as to the substituted energy form, and conversion to renewable energy will qualify. Under the substitution program, a grant is available to consumers (businesses and homeowners) for conversion from oil to gas, electricity (in some cases), and renewable or other resources, of 50 percent of the cost to a maximum grant of $800. This grant can be used for the installation of wood-burning appliances or for solar heating, where they substitute for oil. Financial support also is promised for the expansion of distribution systems (gas and electricity in some cases) to facilitate conversion, and this will be applicable to special off-oil projects in remote communities and possibly some elements of wood supply infrastructure.

Another general, and very successful, program available across the country for the encouragement of renewable energy development is the joint federal provincial program of agreements to demonstrate, on a cost-shared basis, a wide range of new technologies for renewable energy and conservation. Total expenditures are expected to be $300 million over the 1978-1983 period ($113 million is the federal share). It is hoped that these demonstrations will accelerate the introduction, on a commercial basis, of technologies close to economic readiness. A number of these demonstrations are described in the following sections on specific renewable energy sources.

Oil Sands and Heavy Oils

The oil sands and heavy oils of the Canadian provinces of Alberta and Saskatchewan are among the world's largest known deposits of petroleum hydrocarbons. The oil sands cover a total area of more than 53,000 square kilometers in the north of Alberta, with the four main deposits containing about 150 billion cubic meters of crude bitumen. It has been estimated that, with favorable developments of technology, the whole area may yield 13 billion to 31 billion cubic meters of synthetic crude oil, but development so far has shown that its extraction will be slow, difficult and costly. Too fast a growth rate in oil sands extraction could put considerable pressure on the technical, financial and labor resources of the country. Exploitation of the heavy oils of western Saskatchewan and eastern Alberta, where there is as much as 5 billion cubic meters in sandstone deposits 300 to 600 meters below the surface, will depend on developments in enhanced recovery techniques and agreements on pricing policies.

Increasing world and domestic prices for conventional petroleum are making the large-scale production and upgrading of these resources more likely, and with declining producibility from conventional wells, Canada will rely on its heavy oils and oil sands to contribute to the goal of self-sufficiency in oil by 1990. The National Energy Program recognizes the need for incentives for the exploration of frontier and offshore regions and the exploitation of high cost oil, which may not be economical at current domestic prices, and pricing schemes and other incentive mechanisms are under discussion with the provinces.

Two oil sands plants are in operation in Canada (with capacities of 50,000 and 125,000 barrels of synthetic crude per day), and several more are planned. The two companies use surface mining methods of different types, and the hot water extraction process. High environmental standards will be met, including re-landscaping and treatment of the water before returning it to the Athabasca River.

Because of the vast potential of its own resources, Canada has made a contribution to world technology development in this area and is gaining valuable practical experience from its operating plants. Research and development are continuing in all areas of recovery and upgrading, including in situ mining processes, improved flotation processes, improved and more efficient refining, and the reduction of coke and sulfur production. Considerable basic experience is available on resource characterization, including exploration and sampling, research on the physical properties of oil sands and crude bitumen, and the classification and dissemination of information.

With the two plants now in operation, and more proposed, Canadian firms are showing an increased ability to supply equipment and engineering requirements. However, most of the large and more sophisticated equipment, some of which requires exotic alloys that are unavailable domestically, is still imported. In many cases, only a handful of foreign companies service the global market. Canadian engineering services will likely assume particular importance in servicing overseas requirements, but the countries to which such expertise might be supplied are limited. Major accumulations of oil sands and extra heavy oils are limited to nine countries of the world: Canada, the United States, Venezuela, Trinidad, Colombia, Madagascar, Albania, Romania and the Soviet Union, with more than 95 percent in the first three mentioned. Research and test-scale developments are in progress in the United States, the Soviet Union, Albania and Venezuela.

Much of Canada's production of heavy oils (currently production runs at about 15 percent of total crude oil, or about 220,000 barrels per day) has been exported to the United States. The major domestic market traditionally has been the asphalt industry. However, research and development now are concentrating on future production and upgrading for domestic use. Tertiary methods of recovery, which it is hoped will eventually allow yields well above the 10 percent that is obtained by waterflooding, and new upgrading methods are under intensive investigation (including experimental pilot projects). A considerable amount of government assistance is available for this purpose, through federal-provincial agreements, and through the national oil company, Petro-Canada. A dedicated heavy oil upgrading plant is likely to be constructed soon in Saskatchewan, and possibly in Alberta.

In addition to the heavy oils, it is hoped that enhanced recovery techniques now under development will allow greater yields to be obtained from the conventional oil fields of western Canada.

In 1975, the government of Alberta set up the Alberta Oil Sands Technology and Research Authority which has represented a center for research and development funding, technology assessment and information transfer in the areas of oil sands and heavy oils. The main objectives of the Authority's program are to work with petroleum companies to field-test advanced technologies, and to harness the various research capabilities of Canada in the search for new concepts for the recovery and upgrading of bitumen and heavy oils.

The Authority is actively pursuing opportunities for international cooperative programs of technology development including the exchange and training of personnel, technology transfer, and the provision of assitance for resource evaluation. With the United States and Venezuela, Alberta is a founding member of a world information center on oil sand and heavy oil technology.

Oil Shales

Although Canada does possess substantial oil shale deposits, these resources are of low quality, and interest has centered on the more promising and economic opportunities for liquid fuels in heavy oil upgrading, oil sands, and coal liquefaction. Oil shale development is unlikely in Canada in the foreseeable future, although there is some significant activity in the resource evaluation area. This expertise, together with Canadian mining and oil upgrading expertise, would be transferable to oil shale development in other countries.

Alternative Liquid Fuels

Liquid fuels are of particular importance to Canada, because this is the one fuel Canada does not produce in sufficient quantity to meet domestic needs (other fuels are in surplus supply), and because of convenience for transportation, which for a country the size of Canada is a large element in energy demand.

Opportunities for new fuel products and new sources of liquid fuels, such as gas, coal, wood and garbage, are therefore being pursued aggressively.

Canada has a large resource base of coal and is actively developing liquefaction options. In addition, propane is produced in Canada, mainly in the west (105,000 barrels per day). While transportation facilities eastward require expansion, demonstration and financial incentive programs by federal and some provincial governments are beginning, to increase consumer acceptance of this fuel particularly for fleet motor vehicles.

Conventional Hydroelectricity

Canada is one of the foremost countries in the world in hydro development: hydroelectricity supplies about 24 percent of present total primary energy and constitutes more than 60 percent of total electrical production. The provinces of British Columbia, Manitoba and Quebec rely almost entirely on hydro power, while hydro supplies more than half of the electricity in Ontario and the Atlantic provinces. Only the two prairie provinces of Alberta and Saskatchewan rely primarily on other sources of electricity (mainly coal). Electrical consumption is expected to rise by some 20 percent over the next 10 years as oil substitution programs take effect. A number of conventional hydro sites remain unexploited in British Columbia, Manitoba, Quebec and Newfoundland, and could contribute to this growth. The Government of Canada is encouraging such developments and, through the formation of the Lower Churchill Development Corporation is actively participating with the government of Newfoundland in the future development of some 2,300 MW of capacity in Labrador.

Generation facilities in Canada range in size up to the 5,000 MW Churchill Falls project in Labrador, and the 10,200 MW James Bay development in Quebec. Many projects are in isolated locations, distant from population centers, so that Canadian expertise has developed in remote control techniques and sophisticated load forecasting, grid integration and transmission technology, as well as in the development and manufacture of distribution systems designed to serve a wide variety of customers. Canadian firms and utilities (mainly provincially owned) have participated in hydro power development schemes in more than 30 countries, supplying generation and control equipment of their own design and manufacture, providing power planning and market analysis assistance, hydrological surveys and site feasibility studies, and offering support and training services for local personnel. Canada (Manitoba and

Quebec) is recognized as a leader in transmission line technology, particularly very high voltage transmission.

Small-Scale Hydro

There are relatively few smaller hydro sites (under 10 MW) operating in Canada today, and still fewer in the mini- and micro-hydro ranges (under 1 MW). However, rising fuel prices have spawned a number of studies of the power potential of small rivers in Canada, and preliminary estimates suggest that the potential may be more than 67,000 MW installed capacity. The most promising locations are in remote, off-grid areas where small hydro can substitute for local diesel generation (flying in the diesel fuel greatly increases its costs). A survey of British Columbia indicates that more than 50 percent of diesel-fired generation could be displaced in that province, saving (directly) about 250,000 barrels of fuel per year.

Some provincial utilities already are planning or installing small schemes, industrial firms are undertaking research and development to reduce equipment costs, and government-funded demonstration projects are being built to prove concepts and confirm performance: for example, a joint federal-provincial 425 KW demonstration is currently operating in Newfoundland, and a 150 KW unit in Ontario, and four federal-provincial high-head demonstrations ranging from 30 KW to 100 KW are underway in British Columbia. Most components are available from domestic manufacturers, and several Canadian firms report involvement in designing or installing small hydro facilities overseas. One firm has developed a prefabricated mini-hydro package which can be easily transported, and installed at a remote site with minimal preparation and skilled labor, and others are involved in the development and demonstration of micro-hydro units in the 5 to 50 KW range.

For domestic sites, perhaps half would be technically and economically feasible for development at current diesel prices (based on a survey of British Columbia), and consideration is being given to government incentives under the oil substitution program. Equipment for sites of less than 15 MW capacity already is classified in a category allowing a fast (two-year) tax write-off. In addition, a national inventory of sites is being prepared, and a Guidance Manual on survey procedures for feasibility studies of small hydro in remote communities has been produced by Canadian consulting firms with federal and provincial funding.

Geothermal Energy

Canada has considerable geothermal potential in two main areas: the sedimentary rocks of the prairies containing water at about 60°C to 80°C, and the Rocky Mountains, where volcanic action brings rock temperatures into the 100°C to 300°C range, within accessible drilling depths. Surveys are underway to locate and assess the potential of these localities, but there is no operating site in Canada and therefore no bank of private sector expertise.

Two demonstration projects have begun, with federal and provincial government assistance. The first, at the University of Regina, will supply 3 to 5 MW of 60°C water for space heating. A second, being developed by B.C. Hydro, is a proposal to build a 55 MW electrical generation site at Meager Mountain in British Columbia. However, this project is still in the exploration stage and no reservoir is yet confirmed. There is little private industry involvement in either project. Geothermal energy is regarded only as a long-term prospect for Canada.

The main Canadian capability that might be of interest to other countries in this area is in exploration and prospecting, where the considerable expertise and manufacturing abilities built up in the provision of services to the huge mining industry of Canada is readily adaptable to preliminary geothermal exploration (for example, airborne remote sensing, geophysical prospecting and drilling equipment).

A few smaller Canadian consulting firms have direct experience in geothermal resource assessment, gained both in Canada and in countries of South America and Africa.

Ocean Energy

The most important of the various types of ocean energy which may be tapped is from the tides of the eastern seaboard. The Bay of Fundy, Nova Scotia, is one of the most technically promising tidal sites in North America. A feasibility study carried out in 1977, based on a barrage and turbine concept, indicated that supply costs of electricity from one possible site would be 3 cents to 4 cents per kilowatt-hour, about double those for conventional nuclear or coal-electric supply -- suggesting that future trends in prices and technology might render exploitation economically competitive. The Nova Scotia Tidal Power Corporation, with federal government support, recently began construction of an 18 MW demonstration facility, which should be operational by 1983. The system to be used is a scaled up version of systems in use in European river hydroelectric developments.

It is unlikely that other areas of ocean energy will be exploited in Canada for many years. However, Canada is cooperating in a number of the International Energy Agency projects on large-scale wave-generating system design. A Canadian firm, which is expert in underwater pipeline technology, is developing a small, dispersed wave system with units linked by underwater cables. Another firm is experimenting with a novel system for harnessing currents. Canada has little present interest in thermal or salinity gradients. Federal research and development support and incentive programs are concentrated on other areas of renewables which show more short- and medium-term promise domestically.

Canadian skills in the area of ocean energy are thus based primarily on our expertise in the area of hydraulics and of very large engineering projects.

Wind Energy

Wind energy system applications are many and varied, and several technologies appear promising for Canada. The main opportunities in the short- and medium-term appear to be in remote power systems for unmanned instruments and weather stations; remote communities, isolated from the grid, to back up diesel generation; and large wind turbines for grid-connected generation. There is considerable activity in the latter area, including research and development and demonstration projects (both stand-alone and grid-coupled). A major wind resource assessment program is being carried out by the federal Atmospheric Environment Service.

The federal government is spending $26 million in energy research and development funds during the next five years for wind technology development by supporting, for example, special small applications (1 to 3 KW) in telecommunications; grid-coupled field trials in collaboration with utilities (50 KW); development of a wind-diesel hybrid system; a 230 KW vertical axis turbine integrated with a small diesel-fired grid in the Magdalen Island of Quebec (first operational in 1977); and a large grid-coupled Eolus 4 MW vertical axis prototype wind turbine to be built on the St. Lawrence River in Quebec, scheduled to be operational in 1983. The latter two projects are funded by the National Research Council and Hydro-Quebec, in cooperation with the aerospace industry.

Canada is particularly involved in the development of vertical axis wind turbines. Many such turbines are in field trials and are on test in other countries. In addition, other federal-provincial demonstrations are underway across the country, and an Atlantic Wind Test Site is being established in Prince Edward Island.

In the area of incentives, wind generators are exempt from the 12 percent federal sales tax, and under the oil substitution program demonstrations of wind energy (among other renewable applications) will be funded in remote northern communities. In addition, studies by government are continuing on the potential for wind, industrial development strategy and remote area deployment.

In developing areas, wind turbines have other important applications such as water pumping. There is little direct Canadian experience of developing country applications, although the Brace Research Institute has designed and operated wind turbines appropriate for rural tasks. However, industrial capability for component production is good and could expand to meet the needs of foreign markets. Considerable expertise is available in wind monitoring, in planning and site selection and in maintenance.

Solar Heating Applications

Despite its latitude and its harsh climate, there is considerable technical potential for solar thermal applications in Canada. Some applications, although technically feasible, are not cost-effective at this time and will require a continuation of technological improvement and also higher prices of competitive fuels or technologies to make their implementation economically attractive.

Space heating provides the largest single requirement for energy in Canada: approximately 30 percent of the total annual energy requirement is for heating homes, commercial buildings, factories and similar structures. The use of passive solar energy -- solar gain through windows -- is difficult to document, but it is virtually the only present contribution of solar energy to the national energy budget. Solar energy contributes perhaps 1.5 percent of annual household heating requirements. Passive solar heating is beginning to be an important aspect of building design. This is, of course, closely linked with energy conservation strategies for buildings. Because of its climate, Canada has concentrated on the design and construction of extremely energy-efficient buildings, some using as little as 10 percent of the average consumption in existing conventional building.

Active solar heating is the most commonly recognized solar thermal application, including space and service water heating and industrial process heat. Active solar heating employs specific collectors (flat plate, evacuated tube, concentrators) incorporating a heat transfer medium (air, water or other fluid) and possibly a storage system. Most of Canada's effort has been in the area of flat plate collectors using a liquid transfer medium, although there are a few manufacturers of other components. Several firms produce complete packaged systems.

Solar heating systems are not generally economical anywhere in Canada at present. Space heating has the great disadvantage of peaking during the period of lowest insolation, and this, plus competing conservation measures, may severely limit future markets for solar space heating. For the provision of domestic hot water, solar systems may be cost-effective in areas where electricity is oil-generated (hence more costly) if they are owner-installed.

It is difficult to assess the total future contribution of active solar heating in Canada, because of technical and economic uncertainties. Discussions are continuing concerning the advisability of establishing solar contribution goals and associated cost goals for the next 20 years, toward which policy and programs may be directed.

Federal programs in this area began with the renewables research and development program in 1974, and in 1978 several new initiatives were designed to launch active solar heating technologies and support a developing solar industry in Canada. Further initiatives were added in the 1980 National Energy Program.

Current federal programs in this area include research and development support, industrial assistance, demonstrations (in conjunction with provincial governments) and consumer incentives. For example:

- Federal research and development expenditures are $11 million per year, covering product and systems development oriented mainly to provision of service hot water.

- Program of Assistance to Solar Equipment Manufacturers ($4.1 million over two years) provided grants to solar industries to assist in designing and developing solar equipment.

- The Purchase and Use of Solar Heating program calls for the procurement of $125 million of solar systems by the government for its own facilities.

- Renewable and conservation demonstration agreements with the provinces have resulted in expenditures of about $800,000 to date on solar heating, including a 100-unit demonstration of solar domestic hot water in British Columbia.

- A 1,000-unit demonstration across the country of domestic hot water systems cost $5 million and included evaluating and monitoring reliability and performance, and developing preliminary infrastructure.

- A fast (two-year) tax write-off for commercial and industrial solar heating installations.

- The applicability of the $800 off-oil grant to solar heating.

The Province of Ontario, under its new five-year Solar Energy Strategy has recently announced a program to demonstrate and stimulate the market for solar systems, principally for hot water, by providing up to 90 percent of purchasing and installation costs in the commercial, industrial or institutional sectors.

There is a small group of solar industries in Canada, which is maturing with the experience gained under the above programs. The technical challenge is to achieve high performance, reliability and durability and minimal production costs. Canadian production capabilities for water heating far exceed domestic markets at the present time, and will likely continue to do so even with the consumer incentives under the National Energy Program. Consequently several firms are actively exploring foreign markets, and adapting their equipment for tropical use and eventual local fabrication (with local partners). Canadian equipment successfully competes with that from other industrialized countries. Considerable scope exists for joint ventures with developing countries. As with other sources, expertise also exists in the areas of resource assessment, system design and program evaluation which could be transferred to other governments or local industries.

Some other special applications of solar energy exist, such as crop drying, where Canadian expertise and research could contribute to developing country uses, although fabrication would likely be local. Federally and provincially sponsored research encompassing different scales of application for different crops is going on, particularly in Saskatchewan and Ontario. The Brace Research Institute has compiled information on solar crop drying activities, with an emphasis on the needs of the developing world.

Photovoltaics

Electric generation using solar cells in Canada is limited, as in most countries, to very specialized applications in remote areas where reliability and maintenance-free operation is important, and the electrical load is small -- for navigational aids, environmental monitoring devices, rail signals and communications installations. Nevertheless, the speed with which technological developments are occurring in this area, and with which costs are falling, due to aggressive programs of research and development in several countries, means that photovoltaics can no longer be regarded as important only in the dim and distant future. Canada is following world developments closely, with a view to introducing programs at the appropriate time to prove and demonstrate this technology in broader applications, and to help develop markets (both domestic and overseas) for a fledging Canadian industry.

Research and development, funded both privately and federally, is occurring on a limited scale in Canada, on specific aspects of materials technology, cell and module fabrication and system development. Proof of concept and demonstration experiments are beginning, in one case with considerable electrical utility involvement and funding.

Three Canadian firms are capable of producing cells (single crystal silicon) and modules on a relatively small scale, and both these firms and others are capable of designing and fabricating the remainder of the system. Many Canadian firms are interested in developing applications technology, and some already have become active in developing countries with, for example, a unique water pump design. Canada also has acknowledged expertise in micro-electronics and communications technology, making it uniquely suited to developing that particular photovoltaic application, which will be of special use in the developing world. In addition, there is considerable experience in engineering design and systems development in Canadian industry, which will be the most important aspect of photovoltaic applications once the present concentration on cell technology has reduced unit costs to an economically attractive level.

Biomass

Because of Canada's immense forest resources, wood-based industries (including pulp and paper) are among the most important in the country, generating about 8 percent of its gross domestic product. This, plus its vast primary agricultural interests, has put Canada in the forefront of much of the research, development and application activity that is concerned with the use of forest biomass and wood and agricultural wastes, to produce energy and synthetic fuels.

Biomass now contributes perhaps 3.5 percent to total primary energy use in Canada. This comprises mainly the use of wastes in the forest and pulp and paper industries (for example, about 50 percent of the total mill wastes generated are used as fuel). There is also some use of fuel wood in the residential and other sectors. With rising energy prices and the present government programs available to encourage the use of wood and wood wastes, the total contribution of biomass is expected to increase to 6 percent of total energy by 1990.

Federal programs to encourage the use of biomass in Canada include research and development support, industrial assistance, demonstrations and consumer incentives. For example:

- Federal research and development expenditures are currently $7 million per year, with increases expected to cover expansion of effort in the production of liquid fuels. The major component is the Energy from the Forest (ENFOR) program, which finances innovative research and development on biomass energy issues such as improved forest productivity, soil fertility, harvesting technologies, improved combustion technologies including the use of fluidized bed systems, and associated environmental issues. In-house research at the Department of Energy, Mines and Resources includes combustion technology and performance testing of wood-burning appliances.

- The Forest Industry Renewable Energy program provides direct financial incentives to any industry or commercial establishment to use wood wastes or other biomass resources instead of fossil fuels.

- The Development and Demonstration of Resource and Energy Conservation Technology program funds the development of new technologies to produce energy from industrial and municipal wastes.

- The federal-provincial cost-shared demonstration agreements include biomass projects, with about 25 percent to 30 percent of the total funding going to demonstrations of technologies for biomass such as wood gasifiers and municipal waste-burning equipment.

- The off-oil incentive grant under the Canadian Oil Substitution Program will be available for conversion from oil to wood.

- The distribution system expansion funding under the Canadian Oil Substitution Program may be applicable for the development of wood supply infrastructure and related issues.

As well as the direct combustion of biomass to produce heat and/or electricity, Canada is active in conversion technologies, including gasification and the production of fluid fuels such as ethanol and methanol. Canada has, however, many other options (oil sands and other non-conventional oil, propane, compressed natural gas and liquid fuels from coal) that may be more competitive economically. Biomass and wastes do have three important advantages: they are renewable (if properly managed); they are more evenly distributed across the country, thus helping to moderate problems of regional resource distribution; and they call for labor-intensive operations and may therefore confer socio-economic benefits on remote or rural regions.

The following are some of the key areas in which Canada has expertise:

- Forest management: Many private firms in Canada are capable of providing the full range of forest management services. Some have been active internationally, particularly in the area of forest inventory studies (CIDA has financed such studies in more than 20 countries). Many forestry students from other countries have gained their technical training in Canada. Forestry research is a very active area for governments and private institutions, particularly forest regeneration. The International Development Research Center has supported research into the special problems and opportunities of tropical forests. Considerable practical expertise is available in the forest products industry, and a number of Canadian companies manufacture and distribute machinery for cutting, preparing, loading and transporting wood, including a very advanced mechanical tree harvester.

- Rapid silvicultural/biomass production techniques: The Ontario Ministry of Natural Resources in cooperation with the federal government has developed a strong capability in the area of hybrid poplar. Five thousand acres of plantations are already under development and a major expansion of the program is planned. This will coincide with the selection of Canada to lead the International Energy Agency group on research in rapid silvicultural techniques and the establishment of a Biomass Technology Institute in Ontario.

- Wood-burning stoves for heating and cooking: Most Canadian equipment concentrates on heating rather than cooking. However the Brace Research Institute has developed a series of very inexpensive, efficient cooking stoves that burn sawdust, wood or dung, suitable for many developing country conditions.

- Combustion boilers: Canada is a world leader in the engineering, design and construction of energy recovery facilities using wood waste, and this expertise is increasingly being put to use in conversion of other biomass fuels. There are three major manufacturers already very active internationally.

- Gasification: Canada has developed an advanced fluidized bed gasifier which is undergoing its first full-scale commercial trial at a plywood mill in Ontario, where it will burn mill waste. This technology produces gas for heat, and can be adapted to produce synthesis gas which can be used to produce liquid fuel (methanol). There are several other Canadian organizations involved in wood gasification, including the B.C. Research Council.

- Anaerobic digestion: Considerable research is underway in this area in Manitoba, Ontario and Quebec for digestion of farm wastes and sewage. Canada's principal contribution would be in the development of this technology for operation under cold weather conditions.

- Alcohol fuels: Canada has enormous supply potential for methanol from coal, natural gas or residual oil as well as biomass sources. The economics of large-scale production favor coal or natural gas, but the advantages of renewability and wide distribution have sustained interest in biomass as a feedstock. The regional economic benefits have attracted some provinces to this option.

In some locations, cheaper, more competitive biomass feedstocks are available.

Considerable research has been done in Canada on biomass-based production of methanol, particularly from synthesis gas produced by the fluidized bed gasification technique. The market in Canada, however, currently is limited by constraints on the use of methanol in engines designed for hydrocarbons, particularly in Canada's harsh climate. Further technological developments may resolve these problems. Because of its enormous supply potential, Canada could become a leader in methanol technology and could expand export markets for the fuel, and for technological expertise.

Less research has been done on ethanol or butanol from biomass, but the potential for major technical advances makes this a very attractive option for Canada. Of the two main methods of hydrolysis, the basic process for producing ethanol or butanol, the enzymatic route shows greatest promise and is advancing rapidly toward cost-effectiveness. Canadian firms have pioneered the development of an inexpensive pretreatment process for lignocellulosic materials. Several private firms are active in this area, and government support of research and development is to be expanded. Cellulosics (wood) and wastes are the most likely candidates for feedstock: in Canada, agricultural crops tend to have a higher value as food or feed, although dedicated crops are grown for ethanol production in other countries. Canada now produces industrial grade ethanol from waste pulp liquor and has the potential for higher outputs from this source and from food processing wastes. With the rapidly advancing technologies of cellulose hydrolysis however, there is the potential for Canada to produce very large quantities of fuel grade ethanol from wood and other lignocellulosic feedstocks.

The province of Saskatchewan recently announced the building of a 3 million gallon per year ethanol plant, using barley as a feedstock, as well as a feasibility study for a pilot plant to produce ethanol from lignocellulosics. The Province of Quebec, through its alternative energy corporation Nouveler, is financing the development of a methanol plant using gasified wood as feedstock.

Canadian expertise in beverage alcohol production including design of distilleries is considerable, and some of these companies are beginning to explore foreign markets for design and construction of fuel alcohol plants.

In Manitoba, a beverage distillery is being converted to produce ethanol from barley for gasoline blending. Manitoba has removed the provincial road tax on gasohol.

Peat

The resource base in Canada for peat is one of the largest in the world, but the development of this resource has not been pursued to any extent. There have been some studies on the feasibility of using peat for power generation in eastern Canada (New Brunswick), and Hydro-Quebec Research Institute has carried out feasibility studies on using gasified peat to produce electricity in remote areas where peat is abundant, and two thermal plants using gasified peat are at the final planning stage.

Harvesting peat is a particular problem in Canada because of the climate and environmental concerns, and some research is going on to find methods of harvesting throughout the year. In addition, some gasification research and development is being applied to peat, including fluidized bed combustion. In Newfoundland, which has no coal, the pulp and paper industry, with funding from the federal and provincial governments, is experimenting with the use of peat mixed with mill residues to fire steam boilers.

Conservation and Efficiency

Along with the development of oil supplies in Canada and the substitution of domestic resources (including renewable energy) for oil demand, conservation and increased efficiency are key features of the National Energy Program and of the energy strategies of all provincial governments. Emphasis is on oil conservation, particularly in the eastern provinces, but programs are generally not commodity-specific and improved efficiency in the use of all types of energy is encouraged.

Energy demand patterns in Canada are changing, as industries and individuals respond to the steadily increasing prices. There are shifts to more efficient automobiles for example, and industrial efficiency in terms of energy use per dollar of product has increased significantly during the past few years. Government programs can facilitate this response and help to overcome some of the barriers to increased energy efficiency which exist in the marketplace. Many of these programs overlap to some extent with those encouraging the use of renewable energy. For example, increased use of wastes as an energy source is a conservation measure and, because biomass usually is involved, it is also a renewable resource. More efficient building design normally will incorporate the use of passive solar heating or cooling.

All provincial governments in Canada have conservation programs, as does the federal government. Programs encompass information dissemination to promote increased awareness, direct grants or other incentives to remove capital barriers or to increase rates of return, taxation measures, regulation, removal of disincentives to efficiency, research and development, technology demonstration and in-house example.

The principal conservation programs (other than research and development support) of the federal government in Canada are:

Building

- The Canadian Home Insulation Program, which provides grants to householders to upgrade the efficiency of their homes by the addition of insulation and other measures.

- A "super-retrofit" program, whereby the off-oil grant may be used in certain areas of the country for additional conservation measures.

- A demonstration of new super-efficient housing design and construction, comprising 1,000 units to be built across the country.

- The development of new efficiency standards for arctic housing.

- A program to assist municipalities in undertaking energy conservation initiatives in their areas of responsibility.

- Demonstration of enhanced conservation and renewable energy systems in a selected remote arctic community.

- Programs of improved operating efficiency and retrofitting of federal buildings.

- A program of mandatory energy use labelling of appliances.

Industry

- Working with industry on a task force basis to develop efficiency targets and ways of meeting them, and monitoring performance.

- The very effective "Energy Bus" program, whereby computer-equipped vehicles with a program developed to perform a detailed analysis of energy consumption, and staffed by energy analysis experts, visit establishments across the country to assess energy demand and recommend methods of improving efficiency of energy use.

- Provision of funds (cost-shared) to assist industrial and commercial establishments in auditing their energy consumption and implementing measures to improve efficiency.

- Grants to firms in the Atlantic provinces to help finance energy conserving investments.

- A fast (two-year) write-off tax provision for firms investing in qualifying energy conserving or renewable energy equipment.

Transportation

- Introduction of legislation to enforce fuel consumption standards for new motor vehicles (currently voluntary targets exist).

- Establishment of ride-sharing centers, support for driver education programs and fuel economy programs in the trucking sector.

Denmark

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INTRODUCTION

Denmark is more dependent on imported oil than most other industrialized countries of the western world. Oil imports account for about 70 percent of the total consumption of primary energy. With International Energy Agency (IEA) cooperation, Denmark has accepted as a target to reduce oil imports to 11 million tons oil equivalent (Mtoe) in 1985 from the present quantity of about 14 Mtoe. It is expected that fuel saving and fuel switching programs will result in a decline in the share of oil in primary energy consumption to about 50 percent in 1990.

NEW AND RENEWABLE ENERGY SOURCES IN DENMARK

The future aggregate contribution to Denmark's energy supply from new and renewable energy sources is difficult to assess. Danish energy planners expect the share to be 4 percent in 1995. In the longer term, however, the potential will be substantially larger. In recent years, intensive development and research, supported financially by the Danish government, has taken place in new and renewable energy sources. In several areas the development has reached an advanced stage. Industrial production of renewable energy systems has been established for sale on the domestic market and for export. After the increases in oil prices in 1973, growing attention has been devoted to research and development in new and renewable energy sources. In a few areas, Denmark, due mainly to its general lack of primary energy, has a historical tradition for utilizing renewable energy sources. This applies especially to wind power, for which the climate offers favorable conditions. Danish research and development in new and renewable energy sources is to a large extent a result of technological advances in private, often small or medium-sized Danish enterprises. Broad public interest has helped to promote this development.

Energy has for many years been a natural area for research at Danish universities and institutes of higher education. Energy research also is conducted by institutions such as the Riso National Laboratory, the Geological Survey of Greenland and the National Building Research Institute. Several energy research projects are supported by the research councils set up by the government, the Danish Council of Technology and the Danish Development Fund.

Based on the energy policy targets formulated in 1976, the government has launched a number of comprehensive programs in energy-oriented research and development. The first was in 1977.

It is estimated that these programs have covered half the total input in energy research at the national level. With the latest energy research program (ERP) of the Ministry of Energy, the funds allocated to these programs total D.kr. 550 million. Of this sum, approximately D.kr. 200 million will be devoted to research and development in renewable energy sources.

A number of research projects have been implemented in the framework of international cooperation, especially within the IEA. Denmark participates in agreements for cooperation with regard to solar energy, heat pumps, energy consumption in buildings and dwellings, energy storage, biomass, wind energy, coal research and reactor safety. In addition, Denmark participates in the work of the IEA in developing models of energy systems.

There is reason to underline the intensive cooperation on energy research which takes place within the European Community. European Community funds in the amount of around D.kr. 40 million have been allocated to Danish research and development in the energy sector. With the European Community cooperation, Denmark also participates in the development of models of energy systems.

The Nordic countries are engaged in an intensive cooperation in new and renewable energy sources.

Part of this cooperation is exchange of information on Nordic research, development and projects. The aim is to avoid duplication of effort and to analyze in which areas two or more projects on new and renewable energy sources may be coordinated.

Exchange among the Nordic countries of information on development assistance involving energy is nothing new. It is one of the aspects of the regular close cooperation of the Nordic assistance agencies. Cooperation in specific projects would be a welcome addition.

Some new and renewable energy sources cannot, or can only to a negligible extent, be used in Denmark. Consequently, Danish experience in their use is limited. The review presented below covers only those new and renewable energy sources which Denmark, through exports, transfer of technology and/or technical assistance can make other countries share in Danish knowledge and experience.

WIND POWER

In 1957, the Danish power companies started experiments with wind energy for electricity production. In southern Denmark, a 200 KW wind generator, the Gedser Mill, was erected. It produced alternating current direct to the electricity supply network. Later, other research and development projects have been started, comprising large wind turbines as well as smaller local windmills. The Tvind wind turbine in particular has attracted international attention.

In recent years, several hundred small wind turbines with generators have been built, and the number keeps growing. The turbines, many of which are connected to the public electricity supply network, are typically capable of supplying a single or a few households with electricity. As before, they probably will be used primarily in sparsely populated areas. Because of the great variations in wind conditions throughout the year, very large storages of energy would be required if a windmill were to cover the regular energy consumption of a household. In periods with little wind, supplementary energy has to be provided from other sources, for instance from the public supply network. (Conversely, surplus production in periods with strong wind will be supplied to the network). In addition to these minor wind turbines, a few large electricity-producing wind power plants with a capacity corresponding to the consumption of a small urban community have been built. The experience gained in the use of these plants will be taken into consideration in the final deliberations as to the potential role of wind power in Danish energy supply.

The Ministry of Energy and the power companies have built two 45 meter tall wind turbines with a vane span of 40 meters. Both turbines have a maximum capacity of 630 KW.

On the basis of experience gained in the operation of these two plants and the findings of a comprehensive measurement program, it is intended to examine which types and sizes of large wind machines are best suited for Danish conditions. At the same time, an assessment is being made of the possibilities of placing 1,000 to 2,000 large wind power plants in Denmark, taking account of wind conditions, environment and preservation of natural amenities. Noise nuisance from wind turbines may be considerable in the vicinity, but the noise depends on the type and design of turbine. The principal sources of noise are the gear, the generator and the vanes. In determining where to locate windmills, account must be taken also of the risk of cast-off ice in the winter and of vane fragments in case of breakdown.

If, by reducing the cost of construction and/or because of rising fuel prices, it proves profitable to build the large windmills, this might be accomplished by serial production of 150 to 200 windmills per year. It is anticipated that Danish-built large wind power plants will be competitive in the international market.

Among the projects in the research program of the Ministry of Energy is a test station for minor windmills at the Riso National Laboratory. At the test station, manufacturers erect their windmills, and the mills are subjected to testing and appraisal of performance. Test station approval of a mill is required for otaining financial support under the support scheme for development of renewable energy. Furthermore, the test station performs measurements on mills which are already in operation at various places in Denmark.

The comprehensive Danish know-how in the wind power area has resulted in a machinery for production of wind power plants of various sizes and of such quality that the wind power industry has been able to hold its own in export markets. This competitiveness is ascribable to the individual producer's practical experience and the flexibility which the wind power industry has shown in adapting wind power plants to the different technical norms and standards of export markets. An estimated 70 wind turbine units will be exported in 1981.

Today, about 20 Danish enterprises are producing windmills on a commercial basis and their know-how could profitably be transferred to developing countries. They are organized in the Association of Manufacturers of Wind Power Plants.

SOLAR ENERGY

In recent years, solar heating has gained some ground in Denmark. Solar heating supplies energy for hot water household consumption and, to a lesser degree for room heating. The present number of installed plants is estimated to be 2,000 to 3,000. The systems usually consist of a planar solar collector with a layer of glass on top and a water tank for short-term storage of heat. Systems with solar collectors of typically 6 to 10 square meters and storage tanks of .2 to .6 cubic meters are used exclusively for supply of hot water. In Denmark, 80 percent of the solar energy is collected from April through September. With the technology used today, heating of rooms throughout the year by solar energy alone is not profitable because of the problems involved in storing solar energy for use in the winter months (October through March).

The research program of the Ministry of Energy comprises development of more effective solar heating systems. A number of pilot plants of various types have been installed and a facility has been established for testing solar heating systems and individual components.

Because of the marginal conditions for utilization of solar energy in Denmark, the Danish research and development program aims at the development of more efficient systems, including solar collectors with selective surfaces.

The results of the research and development program show that the technical design of the systems can be improved to enhance capacity and lifetime and to reduce the cost of construction.

Although solar heating technologies have proved not to be profitable in Denmark, they may already be profitable in terms of current energy prices under better climatic conditions with larger annual solar irradiation.

In addition, the manufacture and installation of solar heating plants is quite labor intensive. An estimated 2,000 units will be exported in 1981.

A major technical problem in solar heating is the surface material of the individual components. It usually will be necessary in the winter to add antifreeze substance to the liquid in solar collectors. In the event of bursting of a water pipe or leakage in the heat exchanger these additives could cause pollution of the hot tap water. Manufacturers therefore are aware of the need of using durable materials for pipes and of care in the construction of solar collectors. Numerous Danish manufacturers have been successful in devising their own development methods.

Today, the systems of some 30 Danish manufacturers have been approved as eligible for financial support. As mentioned, most of the systems sold in the domestic market are designed for supply of hot water to households. Solar collectors producing energy for heating of individual dwellings are also on the market. Danish industry has achieved remarkable results in the production of large units for use in factories and public buildings. A case in point is Scandinavia's largest solar heating system which is installed as the heating system for a public indoor swimming pool in Denmark. This system is designed with approximately 3 square meters of solar collectors for each cubic meter of pool water.

It is contemplated, with financial support from the European Community and other sources to install a solar cell power plant to serve as a test facility in Denmark. This would be a full-scale research project to examine, among other things, the output of energy from diffuse light which is a predominant solar component in Denmark because of the frequent cloud cover. The total cost of construction of the proposed power plant with appurtenant batteries and of the research activities to be performed will amount to D.kr. 17 million. It would be the first major solar cell power plant to be built in these northern latitudes and the results are awaited with interest. There are, however, no immediate expectations that solar cell power plants could become a profitable alternative to the present power production in Denmark.

With a view to development and collection of operating data, Danish research institutions and a Danish telephone company have conducted experiments in which solar cells were used for the power supply of telecommunications equipment.

Denmark participates within the framework of the European Community and the IEA in international cooperation in solar energy research and development.

GEOTHERMAL ENERGY

Geothermal energy is not utilized in Denmark today, but this source of energy could possibly make a minor contribution to Denmark's energy supply. Research activities are aimed at establishment of geothermal generating plants. The results of a single 3.5 kilometer deep drilling are being studied.

A nationwide study has been conducted to determine the possibilities of utilizing geothermal energy in Denmark. Priority is given to localities providing the best conditions for extraction of geothermal energy and use of the hot water there.

On the basis of the results of these studies, a total sum of D.kr. 57 million has been set aside for 1980 and 1981 for planning and performance of 2 to 4 test drillings and geothermal investigations. It is estimated that about 1 percent of Denmark's energy consumption, corresponding to 200,000 tons of oil equivalent, could be covered by geothermal energy if it proves possible to establish the necessary generating systems.

HEAT PUMPS

Heat pump systems for room heating are already a technologically and economically relevant supply alternative which is being used quite extensively in Denmark (about 3,000 systems have been installed). Systems are being marketed for supply of hot tap water and room heating based on utilization of thermal energy in the ground, in groundwater or surface water, heat in outdoor air or heat from stables.

Developments in the heat pump area have been explosive. This applies both to systems for residential installation and systems for industrial use.

To ensure and enhance the development of heat pump systems and prevent groundwater pollution, the Danish environmental authorities have drawn up guidelines for the establishment of heat pump systems, setting out the technical specifications and control measures required for approval of the systems.

Heat pumps with a typical output of 10 KW are being manufactured in Denmark. The systems marketed are often mass-produced standard systems -- a factor which reduces the cost of production as well as of maintenance and operation.

In addition to systems for residential installation, Danish industry supplies "tailored" systems, for instance for heating large residential areas. In these, large systems as well standard units are used, which cuts capital and maintenance costs. In 1981, about 16,000 heat pump systems valued at approximately D.kr. 180 million will be exported.

In several instances a combination of heat pumps and an already installed source of energy may be a sensible solution. Substantial know-how with respect to such combinations has accumulated in Denmark.

BIOMASS

Due to the high degree of land use for agricultural purposes, Denmark has little possibility of direct utilization of energy from biomass. The sources used are almost exclusively waste products such as animal liquid manure, straw, household refuse and wood residues.

Biogas

About 20 biogas systems have been installed at Danish farms. Initially some operational difficulties were encountered, but it now looks as if it will be possible to establish functional and profitable systems.

Through the research programs of the Ministry of Energy, support is granted for research and development in this field. Furthermore, several pilot plants have been established, financed in whole or in part out of the research funds of the Ministry of Energy.

In the research programs, the main emphasis so far has been on technological development. Some extension, however, is envisaged in the years ahead of research in biological processes -- among other things, the effects of adding of enzymes will be studied.

Aside from being an important source of energy, biogas systems present substantial environmental advantages.

Work in this area has resulted in the build-up of considerable expertise, and a few firms have started or are about to start commercial production of biogas systems.

It should be added that over the years, biogas systems have been installed in connection with treatment of sludge from water treatment plants. Danish firms conduct considerable activities in this special field.

Straw

The Danish agricultural production of straw varies from year to year; on the average, it amounts to 6.5 million tons. Of this quantity, 2 million tons are surplus production for which the farmers themselves can find no use. This portion is therefore available for other purposes, for instance as an energy source. Previously this surplus was burned in the open field. Today, increasing quantities of straw are used in straw-fired plants for room heating of farmhouses, a development which is foreseen to continue in the years ahead. One major straw-fired plant has been built as a pilot project supplying heat to the district heating network of a provincial town.

Refuse

Disposal of refuse in dumps without pretreatment gradually is being replaced by incineration in special refuse disposal plants. Of Denmark's 60 refuse incineration plants, more than half (accounting for about 90 percent of the incinerated refuse) are connected to district heating systems. All new refuse incineration plants are built for district heating. Through continued expansion of refuse disposal by incineration, these plants can make a sizable contribution to Denmark's energy supply. The contribution is estimated to amount to half the total contribution from new and renewable energy sources in this century.

Residual Wood

The contribution to Denmark's energy supply from burning residual wood and firewood is limited and serves only as a heating supplement. Danish forestry is extremely intensive; at the same time, industrial use of residual and surplus wood is increasing. In light of the rising oil prices many house-owners have, however, in recent years acquired wood-burning stoves as a supplementary sources of heating.

HYDRO POWER

In Greenland, there is considerable potential for the use of hydro power. Studies of the possibilities of utilization have not been completed. In the Faroe Islands, too, there is potential for use of hydro power. In the rest of Denmark, hydro power resources are negligible.

France

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INTRODUCTION

The quest for greater energy self-sufficiency is, out of necessity, one of the chief objectives of French economic policy. To achieve this, France has mounted a considerable effort for several years, aimed at the development of new and renewable energies.

This document elucidates the French position with respect to the contribution of new and renewable energies to economic growth and development.

THE OBJECTIVES OF FRENCH ENERGY POLICY

Together with the energy conservation policy, recourse to alternative energies constitutes one of the basic trends of French energy policy. The effort to increase the production and consumption of alternative energies reaches out in all directions, and this -- in addition to the implementation of a nuclear power program and expanding the uses of coal -- implies broadening the share of new and renewable energies in the national energy balance. The present contribution of these energies is still very small. In practice, it is intermingled with that of hydroelectric power (about 14 Mtoe per year or about 7.5 percent of France's total energy consumption) and with that of wood (3 Mtoe or 1.5 percent). However, these energies are expected to play an important role in the French energy balance, indeed a steadily growing role, as testified by the target for 1990: 24 Mtoe to 28 Mtoe, or more than 10 percent of annual energy consumption.

Table 1 provides orders of magnitude anticipated by the French authorities for the contributions of these energy forms in 1990 and 2000, assuming that they are developed to the maximum extent which can be currently anticipated on the basis of the foreseeable states of the art.

TABLE 1. SHARES OF THE DIFFERENT FORMS OF ENERGY
(in millions of toe)

	1979	1990 (targets)	2000 (estimated)
Hydroelectric power	14	14	15

Micro power plants	-	0.4 to 0.5	1
Biomass (including wood)	(3)	7.5 to 9 (5.5)	12 to 15 (10)
Direct solar energy	-	1.3 to 1.5	3 to 5
Wind energy	-	-	0.1 to 0.2
Sea energy (tidal and wave)	0.1	0.1	0.1
Geothermal energy	0.06	0.8 to 1	1.5 to 2
Oil shales and tar sands	-	-	0.2 to 3
TOTAL	17	24 to 26	33 to 42
% of French energy balance	9%	10%	10 to 15%

This table shows that:

- Hydroelectric power, which already makes a large contribution, will not grow substantially because French sites are already satisfactorily equipped.

- Large production increases are expected mainly from solar energy, both in its direct uses (domestic hot water, home heating and electricity generation) and its indirect uses (biomass), and secondly from geothermal energy.

FRENCH POLICY FOR NEW AND RENEWABLE ENERGIES

The new and renewable energies sector in France, which comes under the Ministry of Industry (more specifically its "Direction Generale de l'Energie et des Matieres Premieres," the General Directorate of Energy and Raw Materials), groups a number of public agencies.

Hence it is the directorate which, under the authority of the Ministry of Industry, sets up and implements French government policy in the field of energy, including new and renewable sources of energy and mineral materials. Its activities are significantly facilitated by the fact that in France the state owns the bulk of the electricity production means and a monopoly on distribution, has large interests in many key sectors of the national economy, and has considerable power to influence scientific and technical research.

The Commissariat a l'Energie Solaire (the Solar Energy Commission), under the wing of the Ministry of Industry, is responsible for initiating and stimulating all activities in the solar field (direct solar, wind and biomass). The commission relies on the "Agence pour les Economies d'Energie" (the Agency for Energy Conservation) for spreading the use of firewood and solar water heaters. As for the use of biomass for energy purposes, the commission cooperates with the Ministry of Agriculture to mobilize agricultural and forestry resources and to develop bio-energy applications in rural areas.

The remaining areas of new and renewable energies are covered by various public and professional organizations with more specific purposes, including the following:

- Electricite de France (the French state-owned utility) for hydroelectric and tidal power.

- Bureau de Recherches Geologiques et Minieres (the Bureau of Geological and Mining Research) for geothermal energy.

- Institut Francais du Petrole (the French Petroleum Institute) for hydrocarbons from bituminous deposits and for alternative fuels obtained from biomass, and its subsidiary Beicip for geothermal energy.

- Centre National pour l'Exploitation des Oceans (the National Center for Utilization of the Oceans) for thermal energy from the sea and wave energy.

- Institut National de la Recherche Agronomique (the National Institute for Agronomic Research) and Centre National d'Etude et d'Experimentation du Machinisme Agricole (the National Center for Research and Experiments on Agricultural Machinery) in the area of agricultural and forestry biomass (research, development and demonstration).

- Programme Interdisciplinaire de Recherche pour le Developpement de l'Energie Solaire (the Interdisciplinary Research Program for the Development of Solar Energy), which carries out research activities in the area of direct solar energy and biomass, within the framework of the National Center for Scientific Research.

- Various universities, engineering schools and specialized institutes also contribute to the training and research effort in these areas.

Table 2 gives an idea of the scale of research expenditures and investments made in 1980, by means of resources provided by the state.

TABLE 2. 1980 BUDGET EXPENDITURES BY THE GOVERNMENT AND PUBLIC INSTITUTIONS
(In millions of francs)

Hydroelectric power	2,133
Micro power plants	20
Biomass	100
Direct solar energy	450
Wind energy	2
Sea energy (tidal and wave)	3
Geothermal energy	64
Oil shales and tar sands	50
TOTAL	2,822

This table does not include in-house corporate research and development investments. Furthermore, purchases of home equipment using new and renewable energies should be added to the figures.

The national effort for new and renewable energies will exceed 4,000 million francs in 1980. This figure includes all areas of research, demonstration, industrialization and training activities.

THE IMPLEMENTATION OF NEW AND RENEWABLE ENERGIES

Hydroelectric Power

The current situation may be summarized by the following table.

	TWh/year	in Mtoe/year
Potential resources equipped on January 1, 1980	62.5	13.9
Potential resources undergoing equipment	3.6	0.8
Total economically equipable potential (approximate)	72	16

The large power stations belong to Electricite de France or "Compagnie Nationale du Rhone", and a few belong to self-serving industrial firms. Many small power plants also exist, generally belonging to self-sufficient producers that sell their power output to Electricite de France. Actually, of 1,500 power stations, 1,000 have an output less than 1 MW and produce a total of 1.5 TWh.

Most of the available sites are equipped; some of them have been for a very long time. Estimating the currently equipable potential (10 TWh) is tricky. It is based on an economic comparison of each potential project with the thermal power production units which would otherwise have to be built to supply the same services, but remains somewhat uncertain although it considers present conditions. Studies are underway to combine electricity production with projects for other purposes (navigation, irrigation and flood control) and to derive maximum benefit from modest waterways.

The following measures recently were taken to stimulate the growth of small-scale hydroelectric power production:

- Administrative procedures governing hydroelectric power production have been simplified and decentralized on the departmental (state) level for waterfalls of less than 4.5 MW.

- Financial aid is granted to industrial users who build plants rated at less than 8 MW.

- Local communities are authorized to equip waterfalls.

Biomass

The French government assigns high priority to "green energy," which should contribute the equivalent of 4 Mtoe in 1990, not counting the results anticipated from firewood and charcoal. For the year 2000, the minimum forecasts predict a doubling of this figure.

The priorities laid down to attain these objectives are aimed at the following:

- Expansion of biomass resources: Rivalry exists in the use of the soil (for food crops and energy crops) and also in the use of a given product. Hence, the resources must be expanded by improving forest management and by increasing the productivity of traditional crops or planting new crops (such as energy crops and plantations -- short-rotation coppices, Donax reed, which may ultimately be planted over an area of 60,000 hectares, Jerusalem artichokes, sweet sorghum and water hyacinth). This implies basic research and research/development operations, demonstration activities and the popularization of those techniques deemed suitable. On this matter, the Solar Energy Commission, working jointly with industrial firms and public research institutions, will have a number of machines designed for the collection of biomass.

- Expansion of facilities: Expansion of facilities corresponding to energy conversion techniques currently are under control or about to be in the short term. These include combustion of straw, air gasification (which is ideal for generating stationary motive power or mobile motive power), methanization of liquid animal husbandry waste and use of alternative fuels.

- Rapid advances in techniques: This entails bringing about rapid advances in techniques suitable for use in the short term. One example is the methanization of dry animal excreta, particularly gasification with oxygen leading to the synthesis of methanol. Based on its past experience in the area of non-petroleum fuels, France has assigned priority to methanol (over ethanol) as a partial substitute for petrol as a liquid fuel. Acetone/butyl fermentation is also one of the research projects adopted for the production of alternative fuels.

- Intensification of research: This is aimed at longer-term resources or techniques such as marine and lagoon crops, and processes for the direct bioconversion of solar energy, especially for hydrogen production.

In order to carry these various activities to fruition, public aid is contributed, in line with procedures that depend on the stage of development of the operation and the risks incurred.

<u>Firewood</u>

The share of firewood in France's energy balance in 1990 should amount to about 5.5 Mtoe.

In the next five years, the role of firewood will grow significantly, in line with the general forestry policy established by the Ministry of Agriculture. In fact, considering its estimated 1980 share of 3 Mtoe, the acceleration between 1980 and 1985 should be about 300,000 tons of oil equivalent per year, and 200,000 tons of oil equivalent per year from 1985 to 1990. Available resources which can be put to use are estimated as follows:

Still available industrial waste	.8 to .9 Mtoe/year
Forestry operation residues	.3 to .5 Mtoe/year
Wood from thinning and reforestation operations	.4 to .6 Mtoe/year
Coppices aged more than 30 years to be worked during a 10-year period	1.5 to 2 Mtoe/year

This amounts to an additional potential of 3 to 4 Mtoe per year.

Intensification of the use of firewood implies that:

- The wood industries as a whole will upgrade the energy value of their wastes.
- Some rural households currently heated by paraffin (kerosene) will switch to firewood.
- The use of firewood in communal premises will grow at a rate of 120,000 tons of oil equivalent per year after 1985.

A Firewood Committee was formed in June 1979 to coordinate the activities of the different organizations concerned. The "Agence pour les Economies d'Energies" is henceforth focusing its efforts on the immediate promotion of firewood by incentives to investment for the upgrading of wood waste for energy in the wood industries and for wood-fired heating (400°F per ton of paraffin saved annually) in collective housing and local communities, and in individual homes.

The Solar Energy Commission has made an overall estimate of available resources and has financed a number of regional studies dealing with the assessment of different types of wood usable for energy. The commission is responsible for the development of these resources and the improvement of harvesting techniques, and is laying emphasis on its activities in the areas of innovation and demonstration operations.

Direct Solar Energy

France, a medium-latitude country, has valuable renewable energy resources in the form of solar radiation (2,200 hours per year on the average). The Solar Energy Commission, which is responsible for all public activities involving research, design and support for industry in the solar energy field, has stressed the solar energy in buildings, the photovoltaics industry and solar thermodynamics.

Solar Energy in Buildings: Solar heating units for domestic hot water are already in use by more than 60,000 households, and various incentive measures such as aid for preliminary design and financial assistance were enacted to reach a total of 600,000 solar water heaters in 1985 and a few million units by 1990.

To make sure that supply matches the growth in demand in terms of both quantity and quality, an industrial policy (contracts with eight manufacturers of flat plate collectors which have accepted production and price objectives), a training policy for installers (10 centers equipped in 1980) and a policy for establishing standards have been launched.

The major building ministries (Armed Forces, Youth and Sports, and Health), aware of the need to cut operating costs relating to energy consumption, already have conducted a number of experimental operations. Jointly with the Ministry of Youth, Sports and Leisure, the Solar Energy Commission has set up a specific demonstration operation for the solar heating of 25 open-air swimming pools. The commission will pursue this policy by concluding agreements on specific projects with the major building ministries.

By 1985, at least 10 percent of new construction will use solar energy for heating. By the year 2000, solar energy may contribute to the heating of 2 million housing units out of a total of 20 million.

In the area of increasing public interest and incentives, the Ministry of the Environment and the Quality of Life and the Solar Energy Commission organized, in 1980, a competition involving the ultimate building of 5,000 solar houses, which will benefit from supplementary loans to finance the extra cost due to solar installations. The three essential objectives of this competition were the following:

- To show that a solar house saves energy and is inexpensive in terms of investment and operation.
- To stimulate solar activity by organization of the market and financing guarantees.
- To improve the architectural quality of solar houses to ensure the spread of this type of construction.

Research activities are essential in the area of solar heating, because the goal is to find a solution to the major problem of the gap between solar energy availability and heating requirements. The chief research activities financed by the Solar Energy Commission are concerned with interseasonal storage and thermal modeling of the home.

The Photovoltaic Industry: The overall production capacity of French industry exceeded 1 MW peak power output in 1980, making France, which contributed abroad to vast programs involving pumping, solar television, rural electrification and telecommunications, second worldwide in this field behind the United States.

A public aid plan adopted in March 1980, covering a six-year period, will help create industrial development centers in this branch of activity. This aid is devoted to research, exploratory development, industrial investment and demonstration projects. Also available is non-Solar Energy Commission financing, such as that provided by the "Agence Nationale pour la Valorisation de la Recherche" (the National Agency for the Utilization of Research) and industrial policy credits granted by the Ministry of Industry.

Support for research is aimed at three objectives:

- Technological research, to sustain the observed trend toward lower prices for photovoltaic modules.

- Financing research on alternatives to silicon.

- Development of electronic systems to ensure a better matching of electricity production and utilization.

The Solar Thermodynamics Program: France has launched a vast program involving widely diversified research and development on the overall solar thermodynamics system. Its effort is currently focused in the following three directions:

- The Themis tower power plant, with rated capacity of 2 MW, primary circuit with molten salt and heat storage and 200 53 square meter heliostats. Commissioning of this installation, which will be the world's largest heliostat field, is planned in November 1981 in southern France.

- The 100 KW distributed collector power plant, with 1,200 square meters of segmented-mirror collectors, a storage unit and two organic fluid conversion loops. Commissioning is planned for mid-1981 in Corsica.

- Process heat generation by means of parabolic collectors. The planned demonstration operations are intended to show that it is possible, in a normal industrial environment, to operate a solar system for the production of heat that makes substantial fuel savings possible.

Wind Energy

Experiments are continuing in this area. The French program covers the following topics, listed by order of importance.

- Creation of a wind generator test zone, to be made available to laboratories and industrial firms and designed to compare the performances of different prototypes or machines produced in limited numbers.

- Industrial development of small-sized machines with horizontal or vertical axis (rotor diameter less than 15 meters, power capacity less than 20 KW) that can be used for electricity generation (output 1 to 5 KW and 5 to 20 KW), pumping, heating and desalination.

A distinction is made between machines designed to operate unattended in poor weather conditions and those designed to operate in a supervised location.

- Research and testing of medium sized machines with horizontal axis (rotor diameter 15 to 30 meters, power capacity 30 to 300 KW). This includes wind generators designed to operate to achieve fuel oil savings on self-contained networks already equipped with diesel power plants, wind generators supplying an isolated network to achieve self-contained operation, with or without storage, multi-rotor machines, and grouped wind generators.

- Development of an independent station for the estimation of wind potential.

- Site surveys by simulation in a hydraulic flow.

Sea Energy

In recent years France has devoted the bulk of its effort in this area to tidal power. It is also investigating thermal energy of the seas and wave energy. It is felt in France that the economic prospects for the utilization of marine currents are poor, owing to the prohibitive cost of operating a very low waterfall; moreover, energy from salinity gradients is still in the conceptual stage.

Tidal Power: This is the only marine energy which can be considered as having reached the industrial phase in France. The Rance tidal power station, with a power capacity of 240 MW, has been operating since 1967 and has given full satisfaction from the technical and economic standpoints while providing considerable experience. The KWh cost of this power station is comparable today to that obtained by a large thermal power plant.

France also is conducting preliminary investigations for the possible utilization of tidal power resources in the Chausey Islands zone. The economics and the environmental impact of this costly project, which would represent a capacity of about 12,000 MW for production of 25 TWh (about 5.5 Mtoe), are still far from having been determined. Construction will in any event last about 12 years. France also is trying to give the benefit of its know-how to countries possessing favorable sites (about 20 sites worldwide).

Ocean Thermal Energy Conversion: Ocean thermal energy conversion represents a considerable potential in the intertropical zone where, in the event of the rarefication and rapidly growing cost of traditional energies, the economic value of this form of energy should materialize. The program underway includes two phases:

- A feasibility study of small and medium thermal sea energy power stations (1 to 15 MW). The study already has shown that such open and closed cycle power stations are technically feasible and that they correspond to component sites already manufactured industrially. It also appears that the competitiveness of thermal sea energy, by comparison with diesel, in isolated sites such as Tahiti, is already proven in the pilot plant stage for capacities lower than about 10 MW.

- Implementation of a pilot project in light of the results of the first phase and of some additional tests. This second phase will include a demonstration power station of a few megawatts, serving to show effectively that thermal sea energy is technically viable and economically acceptable.

Wave Energy: The idea of exploiting wave energy is still in its infancy. In this respect, France possesses a valuable resource on its Atlantic seaboard that justifies a research effort. The French program is intended to assess the feasibility, and operating and commercial conditions of small wave power units of under 1 MW to meet the needs of isolated communities (such as on islands and offshore platforms).

Geothermal Energy

A distinction must be made between two types of geothermal energy usage. The first concerns the use of hot water at a temperature generally lower than 100°C, either directly or after heat exchange; this is the "low energy" geothermal application. The second concerns the use of steam issuing from the earth at a temperature above 150°C to produce electricity; this is the "high energy" geothermal application.

High energy applications offer few possibilities of development in continental France. The goals thus consist of developing operations on favorable sites in French overseas territories and of exploiting French techniques and equipment abroad. French laboratories also have launched technological research projects within the framework of tenders issued by the European Community.

On the other hand, low energy applications offer significant possibilities of economic development in France. A large share of low temperature needs (urban heating, hothouse heating and industrial requirements) can be covered by geothermal energy, in view of the scale of the resources and their ideal location in relation to consumption centers. An overall policy for geothermal energy development set up in 1973 has begun to bear fruit. It constituted an attempt to remove the main obstacles encountered and led to various measures: legislative, regulatory, financial, and those relative to geological and mining risks.

The number of projects launched has risen rapidly since 1978. Thus geothermal energy has gone from the research stage to a development stage which serves to set ambitious but realistic goals for the contribution of this source of energy to France's energy balance (.8 to 1 Mtoe in 1990, for investments of 7,500 million francs to be made by that date).

	1980	1985	1990
Number of operations launched	20	150	375
Number of housing units or equivalent concerned	42,000	400,000	1,000,000

Oil Shales and Tar Sands

Although its tar sand and oil shale resources are relatively modest, France has spent several years in a research effort in this area to develop technologies and acquire the ability to upgrade national resources, or in connection with operations abroad. The program to be implemented until 1985 will consist essentially of research and development work. Industrial followup does not appear feasible before 1990 on French territory.

In the area of research, France, and the French Petroleum Institute in particular, attach great importance to geochemical research and the characterization of heavy products to enhance geological surveys and improve methods of using organic matter.

With respect to tar sands, new in situ processing methods are being investigated in the laboratory and are undergoing pilot tests in the field. The horizontal drilling technique, which is especially attractive for tars and deposits distinguished by a very low injectivity, is beginning to be tried out successfully. But the problems encountered by the upgrading of unconventional oils are an obstacle to the development of the use of these resources. To help alleviate this situation, France has decided to build an experimental heavy product processing unit with a capacity of 15,000 to 20,000 tons per year. Moreover, investigations into the use of heavy products as industrial fuels are under way.

Bituminous shales were worked in France on a small scale in the 19th century and until 1957, but no complete inventory of domestic resources was available until the formation of the "Groupe d'Etudes des Roches Bitumineuses" (the Bituminous Rock Study Group, this includes French Petroleum Institute, Compagnie Francaise des Petroles, Societe Nationale Elf Aquitaine, the Bureau of Geological and Mining Research and Charbonnages de France) in 1973. Zones which are favorable to quarry working were thus identified on the eastern edge of the Paris Basin. An initial technical and economic assessment of such a working has been made. Since 1979 new research programs have been set up. They are aimed primarily at completing the work of the study group, particularly by an analysis of the environmental impact of a mining type operation. In addition, studies have begun on the possibilities of in situ extraction.

THE SPECIAL CASE OF FRENCH OVERSEAS TERRITORIES

Within the framework of the French program for the development of renewable energies, a mention must be made of the program applied in the French overseas territories.

In view of their characteristics (dispersion and abundance in tropical zones), renewable energies can meet part of the energy needs of the overseas territories. They can be used to cover essential requirements in isolated places with water pumping and electric power supply (more than 20 percent of homes in the overseas territories are not connected to the grid). Renewable energies can curb the rural exodus and thus facilitate the development and growth of the overseas territories.

New energies also offer significant security of supply: the sun, the wind, bagasse and wood are local resources that can cover 20 to 80 percent of energy requirements. Renewable energies will thus guarantee protection against rising oil prices. In addition, many sites are favorable to high-energy geothermal applications.

Operating costs appear to be relatively limited. Equipment using solar energy or wind energy only requires minimum maintenance, whereas in a local context the scale of operating costs is an obstacle to the development of conventional energy sources.

The Renewable Energies Program in Polynesia

This special research and experimentation program is funded by the Solar Energy Commission, the French Atomic Energy Commission (as operator) and the territory of Polynesia.

Program objectives are:

- Compilation of an inventory of renewable energy resources.

- Experiments with "renewable energy" solutions for the islands (water production, cold production and electricity generation).

- Component testing under the scientific conditions prevailing in Polynesia.

The principal projects already implemented or being set up are concerned with the following:

- Solar and wind pumping at Bora Bora.
- Solar air-conditioning of buildings at Mururoa and at Papeete.
- Electricity for hospital and housing at Tubuaiu and Tautira.
- An 18 KW wind generator (310 KWh per day) at Arutua.

Ireland

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INTRODUCTION

Ireland is deficient in conventional energy sources. It has limited coal reserves and no indigenous oil, although hopes are high that commercial fields may be proven in the next few years. Indigenous hydroelectric power was developed early on, the first station on the river Shannon being built in 1927. Development of the other recognized indigenous source of energy, peat, did not advance significantly until state intervention took place in 1933 at a time when development was not clearly economical.

The primary energy supply mix in 1960 was 30 percent each from peat, coal and oil, the balance coming from hydroelectricity. By 1978, 75 percent of Ireland's total primary energy (TPE) came from oil; the contribution from peat and hydroelectricity had remained static and that from coal had declined. Between 1960 and 1978, Ireland's TPE consumption rose 85 percent to 7.69 million tons of oil equivalent (Mtoe), largely accounted for by increased imports of oil. The rate of increase between 1973 and 1978, however, averaged only 2 percent per annum.

The current level of Ireland's TPE consumption is very low when compared with other west European countries and the per capita consumption is also low. In this regard, Ireland occupies an intermediate position between developed west European countries and the majority of developing countries. This intermediate position reflects Ireland's relatively late industrial development when compared with other European countries, and unlike the latter, energy consumption is expected to grow significantly in future years in line with industrial development. This position is shared with many developing countries.

In 1979 an offshore gas field with reserves of about 30 billion cubic meters came into production, giving a small increase in the indigenous contribution to TPE. Nonetheless, apart from being heavily dependent on one primary fuel (oil), the significant fact concerning Ireland's TPE is that more than 80 percent is imported. To reduce the country's dependence on imported energy, a vigorous search for offshore hydrocarbons is underway. At the same time it is recognized that there is good potential in Ireland for new and renewable sources of energy and research and development work has been underway for a number of years.

Up to the present time (1981), the development or supply of energy in Ireland has been left to private or independently run energy agencies. The formation of the new Department of Energy in early 1980 reflects the importance now attached to energy matters, and will enable central direction to be given to energy policy as a whole and toward demonstrating and implementing new and renewable sources of energy in Ireland.

A coordinated program of research and development into certain new and renewable energy sources was brought into being following the 1973 disruption of oil supplies. The state's expenditure in 1980 for the various research, development and demonstration programs on peat and new and renewable energy systems which have potential in Ireland is as follows:

	IR £ 000's
Peat	252
Wind	127
Biomass	485
Ocean Power:	
-wave and tidal	254
Solar energy:	
-thermal, both active and passive	56
-photovoltaic	35
-photochemical	-
Small hydro	-
Geothermal energy	11

Research, development and demonstration programs in Ireland on new and renewable energy sources involve the following stages:

- Assessment of resource availability.
- Determination of the technical competence available.
- Research, design and construction of a pilot scheme.
- Design and construction of a demonstration scheme.
- Carrying out of integration studies.
- Large-scale implementation.

Only peat has reached the large-scale implementation stage. This was reached in the 1940s after many years of developmental work, and development has continued to the present. Of the other systems, those considered to have the greatest potential for Ireland are wind power and biomass in the medium term and wave power in the long term, although all those listed should make some contribution.

PEAT

Owing to the very limited reserves of coal, wood and natural gas, and the absence of indigenous oil reserves in Ireland, peat resources have been developed as the principal indigenous source of energy. Building on the knowledge accumulated by many pioneer peat producers during the past two centuries, progress in increasing high quality peat prouduction to its present level accelerated rapidly with the setting up by the government of Ireland in 1947 of the semi-state Irish Peat Authority (Bord na Mona -- BnM). BnM was established to develop the peat production industry throughout the country in an economical and efficient manner.

While the reputed area covered by peat is about 1,095,600 hectares, the actual area considered to be deep or large enough for viable production units is about 80,000 hectares, taking into account present production methods and present competitive fuel prices. With the growing importance of peat as a fuel, however, some areas previously considered not viable might tend to become so with the increase in the cost of imported fuels.

Machine Sod Peat

The traditional method of hand cutting peat still is practiced widely in Ireland for domestic use by people requiring fuel near peat areas (bogs). About 800,000 tons per year of machine sod peat are produced by BnM, using large fully automatic machines. Output varies from 5 to 10 tons of dry peat per hour during about 2,000 hours of cutting operation from April to July each season. Cooperatives and private firms also produce a substantial quantity. Air drying of the spread, wet peat usually takes place from April to late autumn. A sod of dry, machine-produced peat measures about 25 x 7 x 7 cm. These sods, about 320,000 tons per year, are used in electric power stations of the national electricity utility. The total installed capacity of these sod peat stations is 120,000 KW. The remaining 480,000 tons of sod peat are sold to industrial (150,000 tons) and domestic (330,000 tons) outlets. The industrial sod peat is, in some cases, broken into pieces of about 5 to 7 cm diameter to suit mechanical stokers.

Machine sod peat made for the above purposes is machine macerated (thoroughly mixed) after excavation and prior to being spread on the bog surface to dry naturally. This maceration has the most important effect of promoting sod shrinkage, densification, irreversible drying and resistance to transport breakage. The calorific value at the normal 35 percent moisture content is 3,500 kcal per kilogram.

Milled Peat

The largest production of peat in Ireland is in the form of milled peat -- peat cut from the surface of the peat bog in layers about 12 millimeters thick into small pieces by rotating spiked drums. During suitable weather, this dries in a few days to 55 percent moisture content or less, and is collected into piles beside railway lines. The peat then is loaded and transported to electric power stations or briquette factories as required. Some of the lightest quality milled peat is diverted to horticultural peat packaging plants.

About 3 million tons per annum of milled peat goes to power stations (of 330,000 KW installed capacity), and 900,000 tons goes to three briquette factories producing 360,000 tons per annum of briquettes. One more briquette factory will be in production shortly (1981) and two are planned to start production in 1984 and 1987.

Briquettes from milled peat contain 10 percent moisture, about 1 percent to 3 percent ash, and have a calorific value of about 5,300 kcal per kilogram.

Horticultural Peat

BnM operates two works for the production of horticultural sphagnum moss peat. A third works is planned. This material is of low density and high water absorption, and is greatly desired by horticulturists for soil improvement to give higher and better crop yields and to increase soil humus. It is not used for fuel purposes.

Reclamation of Bog Cutaways

After all the recoverable peat has been removed from a bog, BnM prepares the cutaway area for other uses. These include the growing of biomass for energy purposes or other agricultural uses. This work is still at the research, development and demonstration stage, but will become of greater significance and extent as more bogs are exhausted in the future. About 1,000 hectares are under reclamation at present.

Production of fuel peat per annum by BnM amounts to about 880,000 tons of oil equivalent, worth at least IR £200 million at 1981 prices. Some 16 percent of the national electricity requirements are generated from peat.

WIND

Ireland is considered to be well-positioned to make use of wind power due to the relatively constant wind regime and relatively high mean wind speeds encountered across the country. At present there are very few wind turbines in use and wind power makes no real contribution to the country's energy supply. It could have a great impact, however, because of the relatively low energy demand and low population density in Ireland.

Several distinct market areas are foreseen for wind power, notably water pumping for supply, irrigation or drainage; water heating by direct mechanical action; and electricity generation, whether by large units owned by utilities, or small to medium-sized, private units.

There are no national projections on the future contributions of wind energy to energy supply. One of the first tasks of the research, development and demonstration work which the government is actively encouraging is to develop such projections as detailed data becomes available. It is expected that wind turbines generally will have to fulfill normal commercial criteria before making any impact on the energy supply situation. Exceptions may arise in the case of remote communities, particularly in the west and in offshore islands, where the wind regime is most favorable.

Ireland has a demonstration program in progress organized by the Department of Energy directly and through the state-owned electricity utility (ESB). In this program, eight or 10 small to medium-sized (10 to 120 KW) commercially available machines will be erected. A range of different machines will be tested, each of them fully instrumented in a variety of locations chosen for their differing wind regimes, each machine serving a different purpose.

The program is intended to demonstrate the present status of the various designs of small wind turbine generators and the energy potential of these machines under Irish conditions. The general experience thus gained, together with the particular experience of operating problems associated with interconnection of these machines and the electricity network, will give training and experience which will enable Ireland to progress smoothly to large machines currently under development elsewhere in the world. At the same time the program is expected to increase public awareness of this renewable source of energy.

There is a limited manufacturing capability for wind machines in two Irish companies at present. On the research side, theoretical studies using statistical methods have been undertaken on the effect of introducing large-scale wind power into the grid. Some fundamental aerodynamic analysis has been carried out, including a novel design for a balloon-borne wind generator.

Internationally, Ireland participates in IEA, United Nations and European Community discussions and research, development and demonstration programs. Thus international activities in wind power are monitored and Ireland participates in international developmental work.

BIOMASS

The term biomass encompasses essentially all growing plant material, ranging from trees, cereals and root crops to algae, either purpose-grown or waste material from other activities such as forestry. It is generally recognized that purpose-grown biomass is best for energy purposes. Ireland is interested in purpose-grown forest biomass but also can make use of forest wastes and agricultural wastes such as pig and cattle slurry.

Forest Biomass

Ireland is particularly well-suited for the production and utilization of forest biomass as a source of energy. The climate is appropriate for the quick growing of many species of both hard and soft woods. The country was originally heavily forested but was denuded in the 18th and 19th centuries. There is a broad experience in Ireland of commercial agriculture and specific experience in traditional forestry. This experience relates to planning and planting new forests and therefore results in efficient, high yielding plantations. For more than 30 years substantial quantities of electricity have been generated from peat, either milled or sod peat, a material very similar to wood with regard to transportation and combustion. Finally the low population density of Ireland means that there are large areas of land available for the establishment of forest. In particular, as peat is harvested for use in adjacent electricity power stations the remaining cut-away bog has potential for afforestation.

Forest biomass produces fuels particularly applicable in Ireland. As a solid fuel, wood can be used domestically or to produce industrial heat or electricity. It also can be gasified and, in the longer term, liquefied for use as a transport fuel.

Since 1976 an active research program into forest biomass for energy has been carried out. Initial work at the Irish Agricultural Institute concentrated on finding species most appropriate to Irish conditions. This work progressed to sylvicultural trials to establish the optimum conditions for growth in different locations, consideration of harvesting systems and tests on the burning properties of woods produced. Together with this practical work the program included economic and systems analysis studies of forest biomass energy, including land use.

The program now has been superceded by a IR £9.2 million demonstration program operated by the BnM and drawing upon services from the Irish Agriculture Institute, the Forest and Wildlife Service and the ESB. Under this demonstration, 400 hectares of short rotation forestry and 200 hectares of single stem forestry are being established, a harvester for the former is being designed and built and existing electricity generating boilers are being adapted in order to burn the resultant biomass. This project will be completed in 1985 and it is expected that it will show the viability of electricity generation from purpose-grown forest biomass.

Ireland leads the world in the above research program on short rotation forestry. Yields from conifers in Ireland average 14 cubic meters per hectare per annum, although the range of yields is from 3 to more than 30 cubic meters per hectare per annum depending on the soil quality and location. Yields from the species currently considered best for short rotation forestry -- salix, populus and alnus -- are expected to exceed those of conifers, although again these will vary with soil quality and location. This is largely due to the high growth rate of these species in their early years when compared with conifers. It has been calculated that by the year 2000, 400,000 hectares of short rotation forestry coppice could yield at least 2 Mtoe each year for Ireland.

All the above programs have been partially funded by the European Community as part of its solar energy research, development and demonstration programs. Part of the demonstration program, the design and building of a short rotation forestry harvester, is included in an IEA Forest Energy Agreement work program.

Additional research work in Ireland is concerned with biomass systems analysis and modeling, work which is carried out within the IEA Forest Energy Agreement. A study also is being carried out into the economic and social impact of biomass production in certain economically depressed regions of the country.

Apart from international activities already mentioned the National Board for Science and Technology, on behalf of the Irish government, is the Operating Agent for the IEA's Biomass Conversion Technical Information Service. This service provides a source of scientific and technical data on all aspects of energy from biomass. Information is presented at regular intervals in the form of abstract bulletins and literature reviews to the participating 13 IEA member countries.

Agricultural Wastes

Research and development work on the production of biogas from agricultural wastes has been carried out in Ireland for some years. Initially the work was stimulated by the need to neutralize and dispose of large amounts of toxic agricultural wastes, particularly pig slurry. The side effect of the production of biogas, however, has always been seen as a useful outcome of the work. Research into the more traditional type of digester at AFT converts pig slurry into methane, which is used to generate electricity and hot water. Further treatment of the residue results in a high-quality, slow-release fertilizer. At the same time, the Department of Microbiology in University College Galway has been investigating anaerobic filter digesters. Laboratory-scale filters have been tested successfully and experimental digesters have given encouraging results with both pig and cattle slurries. A full-scale digester is being built in conjunction with a British university.

Apart from these studies on liquid slurry feedstocks, adaption is being considered to enable solid agriculture residue or energy crops to be utilized in the anaerobic filter digester. This could be in a two stage process, with liquefaction of solids as the first step, and could be developed for use with solid industrial residues.

Ireland's research program is funded partly by the European Community and is designed to take account of and fit in with other international developments in this field.

Conversion of Biomass

The conversion of biomass to fuel has been carried out in Ireland in a small way since the early 1940s. At that time a state company, Ceimici Teo., began distilling ethanol from potatoes. The alcohol was used as an additive in gasoline, up to 10 to 15 percent blend. More recently, with gasoline cheap and plentiful, the average blend has gone down to less than 1 percent. More significantly, imported molasses has been used as feedstock because it is cheaper than potatoes.

With the current need to reduce our dependence on imported energy, conversion processes are being looked at again. The National Board for Science and Technology is to undertake a study of current research, development and demonstration work on the direct combustion of wood in small-, medium- and large-scale boilers. At the same time, a close watch is being kept on the worldwide interest in the gasification and production of methanol from wood and the generation of ethanol by fermentation from various agronomic substrates, such as sugar beet, grass and potatoes.

WAVE ENERGY

Ireland's position on the eastern shore of the Atlantic Ocean at latitudes in the low 50s means that it is ideally situated with regard to wave energy resources. The ocean-facing coastline is relatively long and is exposed to a wide range of wind directions. It has been calculated on the basis of available data that mean power levels off the west coast amount to 40 to 50 KW/m on an annual average basis, or in excess of 400 MWh/m on a year-round average. From these figures it appears that, at an efficiency of conversion of 50 percent, between 100 and 200 line kilometers of wave frontage could supply annual average power in excess of installed capacity in Ireland.

Although Ireland has this enormous theoretical source of energy, it is far from being available for exploitation. It is diffuse and therefore requires large arrays of devices to extract the energy. Also, the source is variable, and while back-up facilities are necessary for periods of calm, devices have to be able to withstand the great destructive forces of storms.

A limited amount of research is carried out in Ireland. Analytical studies of wave phenomena and analysis of wave data are carried out in two universities, while in a third, model devices are tested in a simple wave tank.

Internationally, Ireland is participating in a European Cooperation in Science and Technology project to develop an oceanographic buoy in the Atlantic west of Ireland. At the same time, Ireland participates in the IEA's International Wave Energy Project. In this program, a large Japanese prototype ship-shape device, fitted with eight turbines, successfully completed eight months of sea trials. The resultant data still is being analyzed and it is likely that further sea trials with a modified or second-generation prototype will be carried out.

Ireland is trying to build up analytical and modeling experience to enable the IEA experience in the Sea of Japan to be put to use in determining the most appropriate means of exploiting wave energy potential offshore Ireland.

TIDAL ENERGY

The economics of tidal energy exploitation are directly dependent on the tidal range available and a favorable coastline configuration. A census has been taken of the important large tidal inlets in Ireland which might be suitable for the location of a tidal energy scheme. It can be seen from the results that nowhere in Ireland does the Mean Tidal Range exceed 4m and in only two locations is it more than 3.5m. This figure is well below the tidal range limit which experts consider necessary before exploitation of tidal energy becomes worth considering.

Despite these indications that the basic resource is poorly developed in Ireland, a study is planned of the most favorable site, the Shannon Estuary. This is to determine a theoretically feasible way in which the maximum benefit could be obtained. This study will indicate, without regard to cost, the optimal locations for a barrage and appropriate size and location of turbines and sluices.

Apart from limited bilateral discussions, Ireland is not involved in any international actions on tidal energy.

SOLAR ENERGY

The level of solar energy falling on Ireland has been recorded for many years. Seasonal variation is marked, but the absolute availability of solar radiation in Ireland is considered about half that in the most favorable locations in the world.

Ireland is a participant in the European Community's solar energy research and development program on solar radiation data. Under this program, a European solar radiation atlas is being produced, the first volume of which was published in 1979 and shows maps including Ireland. From these maps, calculated means of global radiation falling on Ireland can be read per month or per annum.

Low Temperature Solar Thermal

Research and demonstration work has been carried out in Ireland on both active and passive solar thermal systems. The design of passive solar houses has been studied and experimental buildings erected. By participation in European Community research projects Ireland monitors research in passive building design elsewhere. The first architectural competition in the country for the design of passive solar buildings suitable for Ireland is being held in 1981.

Active solar thermal systems, particularly for the production of hot water, also have been researched. The lack of interest in the use of solar water heaters in the country is largely due to the very marked seasonal variation in solar energy -- only one-tenth of the yearly total energy falls in the three winter months. At the same time, the daily energy total can fluctuate enormously from day to day throughout the year.

Despite these drawbacks, the design of solar water heaters and of selective absorption surfaces has been studied and pilot tests carried out. As part of a European Community research program, a pilot test facility which simulates a solar heated house has been under test for 18 months. This monitoring is accompanied by analytical work on solar systems design and systems modeling. Ireland also is participating in a European Community demonstration project involving the use of solar panels for heating swimming pools.

Photovoltaic

A limited research program into new forms of photovoltaic devices and new production techniques has been underway in Ireland for a number of years. In 1981, a 50 KW photovoltaic pilot plant will be built to supply electricity to run a dairy farm. The photovoltaic panels will be opearated in association with battery storage, together with the existing electricity grid as back-up. However, despite Ireland's relatively unfavorable level of solar insolation, a positive energy balance is expected for each month of the year. This pilot project is part of a European Community research project whereby such pilot plants will be built and operated in each of the member countries.

SMALL-SCALE HYDROELECTRICITY

A hydroelectricity generating plant with a capacity of 219 MW is operated in Ireland by the ESB, accounting for about 7.5 percent of electricity generation. There are a limited number of locations where schemes from 1 to 40 MW could be built. These are under review by the ESB at present and it is possible that some of these will be developed in time. For the most efficient use of this hydro power it would be necessary to have associated storage, but because this probably would make development uneconomical, less efficient but cheaper schemes without storage would be likely.

The smallest scheme operated by the ESB has a capacity of 600 KW. This scheme was commissioned in 1980 and indicates the current interest in smaller hydro power. Below this capacity there are likely to be locations with potential for local industry or private use, the potential of which is enhanced by the ESB's willingness to buy power from anyone wishing to sell it. An advice service is available to give information to help private development of such schemes.

GEOTHERMAL ENERGY

Geothermal energy has not been utilized in Ireland; indeed it is not even known whether there is any potential for this energy source in the country. There are no known hot springs and no known deep basins with permeable rocks. A few warm springs exist, and a national program is underway to compile geothermal data and measure temperatures and geochemical characteristics of groundwater.

Large-scale geothermal energy sources are not expected to be discovered as a result of this survey. Technical progress in the field of hot dry rock geothermal energy appears to offer the most likely prospect for geothermal development in Ireland. This, however, must wait for a major breakthrough in the technology of developing hot dry rock geothermal energy.

POTENTIAL OF PEAT AND NEW AND RENEWABLE ENERGY FOR IRELAND

Results of analyses by the National Board for Science and Technology recently have been published. For a proper understanding of the results of these analyses it is necessary to consider in detail the information fed into the analyses and the constraints placed on options available in the analyses.

For the purpose of this paper, the projections for renewable energy sources only will be considered:

- Between 1980 and 2010, contributions from renewable fuels are expected to rise from .2 to 1.76 Mtoe, constituting 8 percent of TPE in 2010.
- The hydroelectric contribution will remain virtually constant for that time because of the unavailability of suitable sites apart from some for small-scale exploitation. The expansion will come from biomass, solar, wind and wave energy, mostly after 1990.
- The earliest and greatest expansion comes in biomass, largely because existing peat technologies can be readily adapted for use with biomass.
- Electricity production dominates the use made of renewable resources.
- Residential and commercial usage is dominated by solar water heating.

Whether these projections are found to be accurate or not depends on whether the assumed constraints on the implementation levels of renewable technologies are correct. Research, development and demonstration programs currently being carried out will indicate the feasibility of achieving or exceeding the assumed levels.

The projections of the contribution of both peat and renewable energy in Ireland, 16 percent in the year 2010, are given in detail in Tables 2 and 3. As has been stated, the validity of the projection depends on the assumptions made and the constraints placed on options available. The most significant constraint in this analysis regarding new and renewable energy sources was that the rate of implementation would be conservative. Obviously, if special efforts are made to develop and utilize new and renewable energy sources, these projections will themselves be conservative.

For peat production, it is calculated that reserves will last only for about 40 years. For two of the renewable energy sources, biomass and wind, Ireland is particularly well-placed, and technology is developing rapidly. Ireland is a leader in short rotation forestry biomass research, but this is only at the demonstration stage. The contribution in 2010 could be greater than predicted if the results of the demonstration project are very favorable. Similarly, Ireland is well-placed to use wind energy. If there is a breakthrough in the efficiency and cost of the technology, wind could make a greater contribution to the the energy supply than is predicted in this analysis.

TABLE 1. MONTHLY AND ANNUAL VALUES OF MEAN HOURLY WIND SPEED, 1961-1970

(m/s)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Means
Belmullet	7.24	7.44	7.49	6.83	6.78	6.27	6.16	6.16	6.68	7.44	7.08	7.39	7.0
Birr	4.08	4.23	4.33	4.23	3.92	3.41	3.21	3.47	3.41	3.82	3.77	4.13	3.86
Claremorris	4.84	5.15	5.25	4.94	4.64	4.18	4.08	4.13	4.23	4.64	4.43	4.69	4.64
Clones	5.10	5.35	5.55	5.15	4.69	4.18	4.13	4.13	4.28	4.79	4.79	4.94	4.78
Dublin Airport	5.86	6.11	5.96	5.40	4.79	4.23	4.23	4.38	4.54	5.10	5.61	5.91	5.25
Kilkenny	3.77	4.03	4.03	3.92	3.57	3.11	3.00	3.16	3.11	3.36	3.46	3.72	3.55
Malin Head	8.05	8.31	7.95	7.34	6.62	6.06	6.47	6.32	6.83	8.00	8.40	8.56	7.47
Mullingar	4.38	4.74	4.89	4.64	4.08	3.87	3.87	3.87	3.77	4.18	4.23	4.64	4.33
Roche's Point	7.34	7.24	6.73	6.52	5.96	5.20	5.10	5.61	5.96	6.42	6.73	7.39	6.39
Rosslare	6.73	7.08	6.37	6.17	5.91	5.15	4.69	5.25	5.45	5.81	6.52	6.83	6.08
Shannon Airport	5.61	6.01	5.96	5.61	5.30	4.59	4.69	4.89	4.94	5.35	5.25	5.66	5.41
Valentia	6.37	6.22	5.81	5.55	5.45	4.64	4.38	4.74	5.15	5.71	5.86	6.32	5.56

TABLE 2. PROJECTED AVAILABILITY AND USE OF PEAT, 1985-2010

	MTOE				
	1985	1990	1995	2000	2010
Peat Availability	1.25	1.20	1.20	1.68	1.68
Peat Usage					
Electricity Generation	1.02	.74	.57	.87	.30
Coupled Production	-	-	.04	.06	.06
Briquettes Plants	.14	.12	.11	.09	.10
Industry	.03	.10	.22	.33	.49
Residential and Commercial*	.06	.24	.26	.33	.73
Total	1.25	1.20	1.20	1.68	1.68

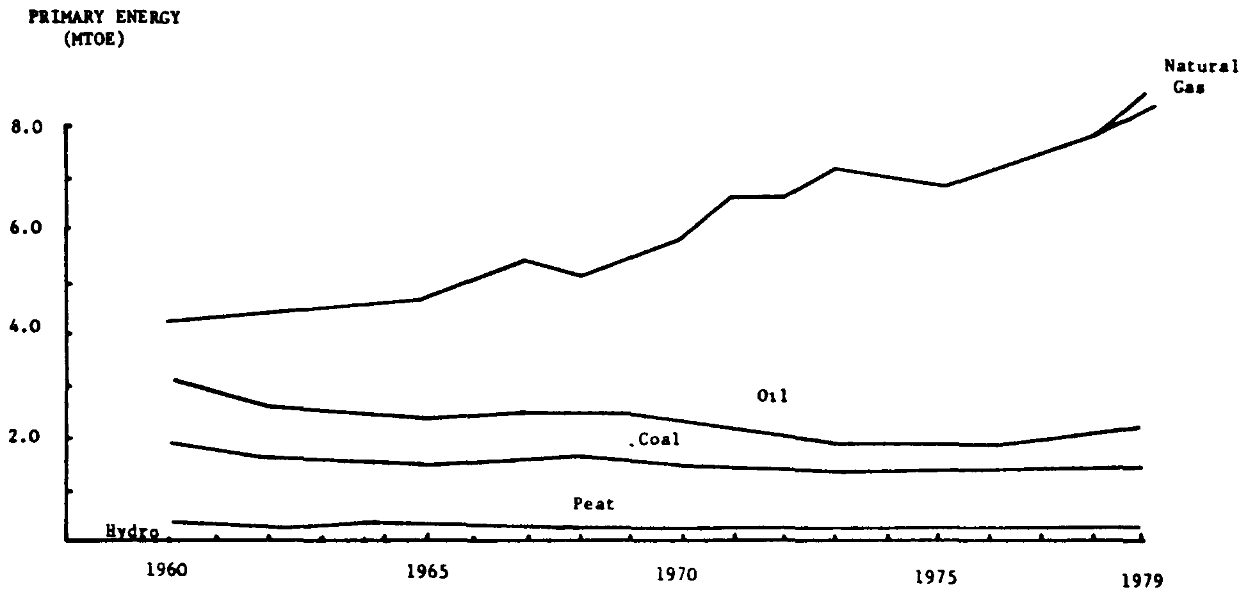
*Excludes Briquettes

TABLE 3. PROJECTED AVAILABILITY OF RENEWABLE ENERGY, 1985-2010

	MTOE				
Renewable Availability	1985	1990	1995	2000	2010
Hydroelectricity	.20	.19	.19	.19	.19
Biomass	-	.12	.39	.87	1.35
Solar	*	.01	.03	.04	.06
Wind	*	*	.10	.01	.09
Wave	-	-	*	.01	.07
Total	.20	.32	.62	1.12	1.76
Renewable Usage					
Electricity Generation	.20	.19	.34	.67	1.12
Industry	-	.10	.22	.33	.49
Residential and Commercial	-	.03	.06	.12	.15
Total	.20	.32	.62	1.12	1.76

*Small

FIGURE 1. TOTAL PRIMARY ENERGY (1960-1979)



Italy

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INTRODUCTION

Italy's energy policy is formulated, directed and coordinated by the Ministry of Industry. The technical body responsible is the General Directorate of Energy Sources. The Ministry of Industry prepares the National Energy Plan, which defines both long-term and immediate energy objectives. This machinery is used to develop proposals considered necessary to promote the use of new and renewable sources of energy (NRSE).

The executive bodies responsible for achieving the energy objectives laid down are the competent public agencies. Each of these, within its own field, is also responsible for planning activities for the use of NRSE with a view to developing local energy resources and reducing as far as possible Italy's dependence on foreign supplies.

The main public agencies dealing with energy are:

- ENI (Ente Nazionale Idrocarburi, the National Hydrocarbons Agency), whose priority task is to ensure Italy's supply of energy resources.

- ENEL (Ente Nazionale Energia Elettrica, the National Electric Energy Agency), which ensures the national supply of electric energy.

- CNEN (Comitato Nazionale per l'Energia Nucleare, the National Committee for Nuclear Energy), which deals with research, development, experimentation and promotion in the field of nuclear technologies, NRSE and energy conservation.

Scientific research including matters related to NRSE, is the task of the Minister for the Coordination of Scientific and Technological Research, which prepares the National Energy Research Plan.

The first program in the energy sector, and in particular in that of NRSE, was promoted and coordinated by the National Research Council. Under this program, in which Italian industries and universities participate, about 40 contracts have been awarded for the application of solar energy in the civil and agricultural sectors and for the production of process heat.

In 1979, the Ministry of Foreign Affairs, the Ministry of Industry and the major Italian industries established the International School for Solar Energy and Other Renewable Sources of Energy, which provides high-level training for Italian and foreign workers.

NATIONAL CONSUMPTION OF ENERGY

In 1979, the consumption of energy in Italy was 149.05 million tons of oil equivalent (Mtoe) or 2.63 tons of oil equivalent per capita. This figure is fairly close to average consumption in the other industrialized countries.

This consumption of primary energy is broken down as follows: oil, 68.8 percent; natural gas, 15.5 percent; coal, 7.7 percent; water and geothermal, 8.3 percent; and nuclear .4 percent.

A special feature of Italy's energy situation is its dependence on foreign sources for primary energy supplies (83.2 percent). Oil is largely responsible for this dependence. It represents 68.8 percent of primary energy supplies.

In 1979, final consumption of energy amounted to 108.1 Mtoe, broken down as follows: industry, 35.9 percent; civil sector, 28.1 percent; transport, 24.9 percent; agriculture and fisheries, 2.3 percent; and non-energy uses, 8.8 percent.

Final uses of energy were: 24 percent in the form of oil; 12 percent in the form of electric energy and the rest for the production of heat (23 percent high temperature, 8 percent medium temperature and 33 percent low temperature).

In view of its favorable hydro-geological situation, Italy will make substantial use of water and geothermal sources. At the moment, these sources meet 27 percent of national electricity demand.

The use of other renewable sources (such as solar, wind and biomass) has gone beyond the experimental stage. Many advances have been made but the contribution of these sources to the satisfaction of national demand for energy will be marginal over the short and medium term.

OBJECTIVES AND POLICIES FOR 1990

Although calling for an increased supply of between 3 and 3.5 percent per year, the National Energy Plan for 1990 aims at holding back total demand to 200 Mtoe. This will be achieved by an active policy of conservation designed to gradually reduce the coefficient of consumption elasticity to 0.7. At the same time, Italy will reduce the share of oil in the consumption of primary energy. For the moment, it will be frozen at the present import figure of 100 Mtoe. Coal, nuclear energy, gas and NRSE will be developed fully.

To ensure the security and continuity of supplies, the objectives are to diversify sources as regards type and area of production and to build up sufficient strategic reserves.

In addition to this supply policy, Italy already is making technological choices which will help its industries improve the quality of their products and sell them on the international market.

ROLE OF NEW AND RENEWABLE SOURCES OF ENERGY IN ITALY

Background

According to the National Energy Plan forecasts, new and renewable sources of energy will account for about 7 percent of energy demand by 1990. By that time, allowing for increased consumption, 4 Mtoe of oil will have been saved. Most of the contribution from NRSE will come from an expanded hydroelectric sector. Residual water resources are to be tapped and formerly abandoned hydraulic power stations reactivated. In view of the expected success of current exploration and that planned during this decade, geothermal sources should allow a subsequent oil savings of about 1 Mtoe. A similar saving should be achieved by the use of NRSE, especially solar energy.

Solar Energy

Flat Plate Collectors: In Italy, low-temperature solar technologies requiring flat plate collectors are well advanced. Current research is now concerned with systemization and heat storage (day/night and interseasonal).

In final uses, almost one-fifth of national energy demand is absorbed by the production of low-temperature heat. Obviously, therefore, the spread of this technology can play a major role over the long term.

At the moment, the steadiest demand is for low-temperature heat for civil, agricultural and industrial purposes obtained from solar collectors rather than electric heaters. In 1979, about 60 firms produced a total of about 100,000 square meters of flat plate collectors. Italian production is highly diversified: manufactures include regular plates, plates with selective surfaces and plates with absorbers made of steel, aluminium and copper.

With a view to eliminating undesirable uses of electric energy, ENEL is conducting an intensive promotional campaign for the replacement of electric heaters with solar heaters. Its programs are aimed at the installation of 200,000 solar heaters in the next three years and 1 million by 1990.

The domestic market should expand considerably with the entry into force of Law No.655, which provides incentives of up to 30 percent of the cost of solar installations.

The government is studying closely the problem of the quality of the solar products marketed. Many centers are engaged in checking the conformity of products with the claims of producers and in providing certificates of reliability.

Concentrating Collectors: Italian industry also has mastered the technology of parabolic and cylindrical/parabolic collectors. It has consolidated this experience with the operation of important pilot projects in Italy and abroad.

The limited use of these collectors is justified even though the medium-temperature heat produced absorbs a little less than 5 percent of total demand in final uses.

Italian industry is taking part in the building of the Almeria plant, projected by the International Energy Agency, which includes collectors covering a total area of 10,000 square meters for the development of 500 KW of power.

Cylindrical/parabolic plants for the production of process heat already have been built in the textile, tanning, chemicals and food sectors. Two twin plants have been installed on the islands of Lampedusa and Pantelleria for the desalination of sea water with multi-stage systems.

According to the National Energy Plan, in the next three years the national energy agencies (CNEN, ENEL and ENI) will carry out a $10 million program for the installation of 10,000 square meters of collectors with different technologies of use and for the manufacture of components.

The agencies will be responsible for the compilation and dissemination of results.

Central Tower Plants: In this sector, Italian industry has more than 20 years of experience and has achieved brilliant successes, which places it in the forefront of world development.

This experience has gone into the construction of the tower plant at S. Ilario near Genoa, the first of its kind in the world, built in the early 1960s on the initiative of Professor Giovanni Francia under the sponsorship of the CNR and with the cooperation of Italian industry.

The experiments, conducted successfully, have enabled Ansaldo to acquire technical mastery of ground reflectors, solar tracking, the thermic cycle and the receptor or focal point. The first power station at S. Ilario was of 15 KW and consisted of 30 square meters of reflectors activated by "Francia" tracking motors. Subsequently, Professor Francia designed the fourth plant of 90 KW with 135 square meters of reflectors operated by 143 tracking motors.

The tower plant of Adrano (Sicily), generating 1 MW and sponsored by the European Community and operated with Italian, French and German cooperation, has enabled Ansaldo to design a special boiler for which the prototype was the receiver for the present S. Ilario plant.

A unit with tower-mounted and ground reflectors has been built by Ansaldo of Genoa on behalf of the Institute of Technology of Georgia University (U.S.).

Italian industrial efforts in this sector are directed toward the export of technology to the developing countries, where the lack of electricity grids justifies the installation of such plants to satisfy the needs of self-contained and isolated communities.

Italian industry is participating in the European Community pilot project, which will have a thermodynamic system at two temperature levels for industrial processes.

Photovoltaic Conversion: Photovoltaic conversion offers the most encouraging prospects for the production of electricity, especially for small-scale use in self-contained and isolated localities. The present cost of photovoltaic systems still prevents large-scale use in countries with highly integrated electricity grids, although today (and even more in the future) photovoltaic installations may be technically and economically advantageous. Italian industries, especially those linked with state agencies, have prepared development programs for the provision of complete systems for a variety of uses.

Under the new National Energy Plan, public buys will permit the installation of photovoltaic plants up to 1 MW per year in 1983 and 10 MW in 1990.

It is expected that by the end of the 1980s the industry will achieve an annual production of 50 to 100 MW.

Besides research activities, coordinated in the past few years by the National Research Council, Italy is developing a pilot program which includes the installation of photovoltaic systems of various sizes. Recently, the National Electricity Agency and CNEN decided to plan and build in southern Italy, where the climate is similar to most Mediterranean countries, a generating plant with a peak production of 1 MW. This project, known as Delphos, will be the biggest photovoltaic plant in the world.

In this field Italian industry also is working under a number of bilateral agreements between governments. Programs have been prepared for the implementation of projects in arid or isolated areas involving direct intervention or cooperation with local units.

Wind Energy

Both the theory and practice of wind energy technology, which is still evolving, are relatively simple: raw materials are cheap, there is a maximum transformation of energy and operating costs are low, being confined almost exclusively to labor.

According to our estimates, the cost of a kilowatt/hour of power produced by small wind generators (80 percent fixed costs) should be economically competitive in the next five years in rural areas not served by electricity grids.

In the research field, CNR and CNEN are preparing a complete wind map with exact indications of energy needs and the presence or absence of electricity grids. At the same time, industrial research and development is moving in three directions: wind installations with storage and hybrid installations combining wind with photovoltaic and biomass.

Among the most important developments we may cite:

- A wind-powered motor (CSN-0501) generating 4 KW with a wind speed of 10.5 meters per second, built by CESEN (Finmeccanica).

- The building by ENEL-Fiat of 50 KW prototypes with winds of 12.5 meters per second.

Biomass

Technological processes for the use of biomass (disposal of urban wastes, direct combustion of agricultural residues, biogas, biomass and alcoholic fermentation), generally well-known, are being developed in Italy also, with a view to their improved application.

The problem of how to get rid of urban, industrial and agricultural wastes has existed for some time because of its impact on the environment. With the advent of the energy crisis, we have had to rethink this problem and search for appropriate solutions whereby we can recover these byproducts in order to produce energy. At the moment, as the latest progress shows, we have more or less acquired the necessary technologies. Strenuous efforts now are being made, in the research field, to reduce the costs of installation and increase the efficiency of biomass operations.

Regarding the direct combustion of wood and lignocellulose residues in general, studies are being conducted of methods of rationalizing harvesting and storage operations, the efficiency of combustion and the possibility of automating the loading of furnaces.

Regarding biogas (methane gas obtainable from the anaerobic digestion of animal wastes, urban sewage and other organic residues), Italy has launched a research and development program entailing substantial finanacial investment.

Italy also is involved in the transformation of cellulose residues into ethyl alcohol.

Incidentally, a new interest is being shown in the first part of the process, the transformation of cellulose into sugar; the second phase may be tackled by the traditional technique of alcoholic fermentation.

In the biomass sector, Italy is conducting a series of studies designed to ascertain what "energy crops" are best adapted to the country's climatic and agricultural conditions, which are not very favorable.

Attention also is being given to the use of ethyl alcohol and methyl alcohol as fuel substitutes. A comprehensive program of research and development has been organized with two main objectives. CNEN has reached an advanced stage in experiments for the transformation to ethyl alcohol by hydrolysis of cellulose products discarded in agricultural operations (straw, clippings and maize stalks). ENI already has programmed a pilot plant on an industrial scale for transformation from gas or coal (mainly of national origin) to methyl alcohol.

Hydroelectric Energy

Water is the most important energy source in Italy.

At the beginning of the 1960s, this source was able to meet almost the total demand for electric energy in the country. It gradually has been superseded by oil to the point where, in 1980, the production of hydroelectric power (48 billion KWh) met 26 percent of this demand.

ENEL has carried out a pilot study of the remaining hydroelectric resources still technically harnessable, apart from their economic desirability.

The results of this study show that water power will contribute about 7.5 billion KWh per year. The study makes provision for some 60 small generating stations, most of which should be in operation by 1990.

Special mention should be made of pumping stations, a sector in which Italy has achieved a first-rank position in the European Community.

As is well known, these stations do not actually increase the energy supply but help to regulate it by controlling the changing pattern of consumption over the days, weeks and seasons.

Pumping stations already built, or in the building or planning stage, will account for a total power supply of more than 7,000 MW. They are situated along the Alpine range near the Italian frontier, close to the primary European grid. This will enable Italy to exchange substantial amounts of electricity with other interlinked European countries. It will be able to export "power services" and also to balance the loads of these countries by importing electric energy from them.

Geothermal Energy

After water power, geothermal energy is a fairly important source of renewable energy in Italy.

In this sector, Italy can claim a unique experience because it was in Italy, at Larderello, that geothermal energy was used for the first time, at the beginning of this century, to produce electricity.

At the moment, Italian geothermal sources at Larderello, Travale and Monte Amiata constitute an installed power of 240 MW. They account for an annual production of 2.7 billion KWh, or about one-third of world geothermal production and 1.4 percent of Italian demand.

Italy's remaining geothermal resources (according to ENEL estimates) should yield an installed power of about 2,000 MW and a potential of 900 billion KWh in 50 years (the period during which this resource is expected to become exhausted).

Low-temperature geothermal resources offer a much more reliable supply. They yield geothermal fluids at temperatures lower than 130°C. Obviously, their development depends on an adequate demand for heat near the geothermal sources.

Systems based on hot dry rocks are interesting from the point of view of technical development. But their industrial use is still far off and depends on the acquisition of suitable technology and the solution of numerous problems.

Also of technological interest are Italy's "magmatic" systems. Their industrial application is also a long way off. In the Italian geological situation they are related to the dry hot rocks systems.

The operational programs of ENEL and ENI, which are conducted as joint ventures in the geothermal sector, are expected to result in a gradual increase in the production of geothermal electric energy between the limits cited above. By 1990, the recovery of geothermal fluids for heating purposes will yield about 200,000 Mtoe.

The two agencies also are involved in the development of new methods of exploration and operation and in the improvement of technological and scientific know-how in all sectors of geothermal energy.

CONSUMPTION

As we have seen, Italian industry absorbs about 45 percent of total energy demand. In recent years, however, the rate of increase of industrial consumption has slackened as a result of a decline in the use of energy by heavy industry. This decline has followed a more careful policy aimed at the greatest possible reduction of waste and the improvement of the efficiency of productive processes.

Regarding the applications of NRSE in the industrial sector, the pilot projects launched by certain public agencies have stimulated demand for the production of low-temperature process heat through the use of technologies such as solar ponds, flat collectors and parabolic collectors.

By 1990, the use of solar energy for the production of low-temperature process heat will yield an annual saving of about .5 Mtoe. Numerous pilot projects are planned during the next three years with a view to tackling and solving such problems as maintenance, integration with other sources, loading diagrams and storage.

Altogether 45 pilot projects will be carried out in the various industrial sectors. They will cost about U.S. $5 million, including partial financing of the investments.

Civil Sector

The civil sector consumes about 30 percent of Italy's energy demand. Heating of premises absorbs about 74 percent; the production of hot water for hygienic and sanitary purposes 10 percent; electricity requirements (lighting and other domestic use) 10 percent; and cooking 6 percent.

The production of hot water for sanitary purposes offers the broadest scope for the use of solar energy. As already seen, ENEL, in cooperation with Italian industry, is preparing a plan for the installation of about 200,000 heaters in the next three years and 1 million by 1990.

A project for the distribution of methane gas in southern Italy is in the development phase. Under this project ENI is to work out a three-year plan of action designed to provide, besides the methane gas, a gas/solar system for the production of hot water for sanitary purposes.

Additional savings of oil in the building sector may be achieved through the use of geothermal fluids and of space heating with waste heat recovery and joint production of electricity and heat.

For new buildings, and especially public buildings such as hospitals and schools, full use will be made of thermal insulation systems and passive solar installations which will reduce energy demand by 40 percent.

Agriculture

Energy consumption to meet the production requirements of the agricultural sector represents about 2 percent of national energy demand. This consumption is closer to 10 percent if we include the energy resources employed in activities related to the processing of agricultural commodities, in the production of technical aids such as fertilizers, chemicals and farm machinery and in the satisfaction of the domestic needs of the rural population.

In view of the probable growth of this sector, we may foresee a subsequent increase in energy demand, while the use of NRSE may to a certain extent accelerate this development. In particular we may expect more widespread mechanization because of the fragmentation of the system, for which the use of new sources of energy are especially favorable.

To attain these objectives, coordinated action is planned to stimulate the development of technologies adapted to the specific needs of the system.

The main initiatives are focused on the production of low-temperature heat for agricultural processes such as drying and storage; for greenhouse production, a sector in which Italy, with more than 14,000 hectares of greenhouse crops, leads the world; and for the air conditioning of buildings.

In the agricultural sector, we are considering the possibility of using combined generating plants producing electric and mechanical energy for servicing the machinery and the heating installations needed for the above processes.

These combined plants will use renewable sources of solar origin (direct or indirect), wind power or biomass conversion of existing byproducts of vegetable or animal origin. It is calculated that the recovery of 50 percent of potential capacity will save about 2 to 3 Mtoe per annum.

The actions planned for 1980-1983 concern essentially the adoption of public incentives (through the necessary legislative provisions) and the dissemination of the results of experiments designed to save energy and use renewable sources in agricultural and food-processing establishments.

In this three-year period, integrated systems will be built in at least 50 such establishments scattered throughout the country.

The above description may serve as a fairly representative initial picture of how renewable sources may be used in the agricultural sector to replace, completely or partially, the traditional sources, with a view to meeting the needs of crop-raising and stock-breeding under different climatic conditions.

LEGISLATIVE AND FINANCIAL ACTION

Through the adoption of a series of state laws, Italy is providing incentives for the conservation of energy and for the use of NRSE in all final user's sectors.

The National Energy Plan provides triennal programs for the development of NRSE technologies and of industrial initiatives for the production and operation of plants, systems and components for the utilization of these sources.

In particular, the production of electricity has been liberalized in cases where single plants generate less than 3,000 KW and combined plants less than 500 KW. The essential points of the law are concerned with the allocation of resources among the various sectors.

For the air conditioning of buildings and the production of hot water for sanitary purposes with the use of NRSE, 100 million lire have been allocated during 1981-1982 as a capital contribution (30 percent of the investment cost) under a regional distribution plan drawn up by the Interministerial Committee for Economic Programming.

For the limitation of primary energy consumption, 120 billion lire has been allocated in the first biennium as a contribution to interest costs.

Authorization also has been given for the expenditure of 40 billion lire during the biennium 1981-1982 as a capital contribution (30 percent of the investment cost) to local authorities or to autonomous electricity enterprises which build distribution networks for heat recoverable in electricity-generating stations from exhaust fumes or the burning of waste.

To expand the use of NRSE, capital contributions up to 41 billion lire (30 percent of expenditure) have been made in 1981-1982 to undertakings which build pilot projects, prototypes or specific devices with low energy consumption.

Finally, in 1981-1982, the expenditure of 50 billion lire has been authorized as a capital contribution for the extended use of hydroelectric plants using small-scale water concessions.

Netherlands

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INTRODUCTION

Although the Netherlands has its own supply of gas, it is still very much concerned about the world energy situation.

Gas supplies will diminish rapidly in the next 20 years. New discoveries to compensate for the high rate of production have not been made, as originally was expected. The declining production of natural gas, which is evident from exports, domestic consumption and -- a factor which is partly linked to both of these -- the increase in energy imports, has very serious economic consequences.

The Netherlands has fewer options to improve the energy situation than many other countries. The density of the population means there is a limit to the extent to which high-grade sources of energy, such as oil and gas, can be replaced by coal and nuclear energy, for example. Moreover, it is extremely difficult to plan the balanced development of the Dutch energy situation in the mid-term, partly because the prospects of new and renewable energy sources contributing to energy supplies in the Netherlands are very limited.

Working on a number of assumptions, the Central Planning Office (CPB) calculated the development in energy consumption in various sectors up to the year 2000 on the basis of certain policies.

Table 1 shows how consumption could be spread among various sources of energy.

Efforts to improve the energy situation in the Netherlands in the next few years will concentrate on restraining the demand for energy and using more sources of energy (diversification). The development of new and renewable sources of energy is part of the policy of diversification.

NEW AND RENEWABLE SOURCES OF ENERGY

At present, new and renewable energy sources make practically no contribution to energy supplies in the Netherlands, and there are no firm figures available yet for the role they will play in the future, because their various applications still are being researched and developed. All the reports published to date estimate that their maximum contributions will be relatively small. The estimates for the year 2000 vary from 100 to 200 PJ (1 PJ equals 10^{15} joules, or about 2.5 to 5 Mtoe), but they are based on estimates for levels of production costs which may not be socially acceptable. The use of new and renewable sources of energy and thus their contribution to the energy supply in the Netherlands is dependent on the increase in the energy price. If the rise in energy prices is steeper than expected, both the absolute and the relative contribution of new and renewable sources of energy will increase.

Once there is more certainty about the applicability of alternative energy sources, target figures will be drawn up. However, some initial estimates are given below.

Solar Energy

This section concentrates in particular on the application of solar energy for space and water heating. For now, the large-scale use of solar cells to generate electricity does not seem feasible because of:

- The expected costs of the system.
- The low yields per surface unit in the Dutch climate.
- The problem of integrating a varying supply into the electricity grid.

Therefore, the main application of solar energy in the Netherlands will be to provide low calorific heating.

In its report entitled "Zonneenergie voor Verwarming" (Solar Energy for Heating) a National Energy Research Steering Group working group estimated the possible importance of solar energy in the Netherlands, assuming that in the long term it could meet some of the heating requirements in one-half to two-thirds of homes and other buildings. This means that the ultimate contribution made by solar energy could amount to about 5 percent of domestic energy consumption. As the investment costs of the installations required will be large, solar energy clearly will have to be introduced over a period of many decades. Space heating with solar energy will be incorporated in new buildings first of all, but as the average life of houses and other buildings lies between 50 and 100 years, this is not expected to bring about the rapid introduction of solar energy. The working group has calculated that in the year 2000 the maximum contribution that could be made by solar energy would be 40 PJ (1 Mtoe).

Wind Energy

It is difficult to estimate the potential importance of wind energy because of its numerous possible applications, such as centralized and decentralized electricity generation, polder drainage and heating. However, it could make a contribution to the Netherlands' energy supplies, particularly if used for heating and generating electricity.

The estimates made in a number of studies vary from a capacity when installed to generate between 1,500 and 2,500 MW of electricity in the year 2000. Taking into account that installations can influence each other, that they do not all produce simultaneously, that there is an average period of time when machines are not working because of faults and maintenance work and that they are not productive all year, they could make a contribution of roughly 2 to 4 TWh in the year 2000, thus making a savings in primary energy of 20 to 40 PJ (about .5 to 1 Mtoe) possible. If, in addition, wind energy installations with a capacity of perhaps 500 MW were erected for heating purposes, this would yield a further contribution of about 1 TWh (.1 Mtoe).

Geothermal Energy

There is little detailed information available on the potential of geothermal energy in the Netherlands. However, it is known that at a depth of 1,500 to 3,000 meters under the surface there are water-bearing rock strata with a temperature of 60°C to 120°C which could, in principle, be used in industry as well as, for example, district, domestic and glasshouse heating.

In the future, geothermal energy will have to compete with other new forms of energy savings, such as the use of industrial waste and solar energy. At present, it is being investigated whether a geothermal experimental project could be implemented in the Netherlands. Assuming that about 50 projects could be created by the year 2000, geothermal energy could contribute from 5 to 10 PJ (about .1 to .3 Mtoe).

Energy from Water

There is little potential for conventional hydroelectric power in the Netherlands because the country is so flat. It is not possible to produce energy from the River Waal, the major Dutch waterway, because international conventions decree that shipping shall have free passage. Research into the possibilities of producing energy from the other rivers has shown the technical potential to be slight. The cost of generating electricity in this way would be unacceptable. It would only be economical if sluices and dams had to be built anyway by the Public Works Department in connection with water management and their cost did not exclusively derive from generating electricity. The potential that could be exploited profitably is therefore much lower.

Other forms of water power which have been studied are tidal energy, wave energy and ocean thermal energy conversion.

In general, enormous installations and hydraulic engineering works are required for wave and tidal energy, and their size can present serious problems. The costs are so high and the potential contribution so low -- owing to the lack of favorable circumstances -- that it would not be justifiable to apply these methods yet.

As far as ocean thermal energy conversion is concerned, the temperature gradient in the waters along the Dutch coast is too slight for economical production to any extent. In fact, the application of ocean thermal energy conversion will, for the time being, be restricted to tropical regions.

Biomass, Wood and Charcoal

The cultivation of biomass (fast-growing crops and algae) is another way of using solar radiation, by means of solar energy stored in plants through photosynthesis. A number of countries, including Brazil, the United States, France, Ireland and Sweden are considering using this method to contribute to their energy supplies.

The method has a very low overall efficiency (less than 1 percent), and is therefore hardly suitable for the Netherlands because the land area required could otherwise be used to produce food. By way of illustration, a simple calculation shows that the total surface area of the northeast polder (35,000 hectares) would be required to fuel an electric power station of about 150 MWe.

Energy from Waste

An analysis of the possibility of using household and industrial waste as sources of energy has shown that the energy savings already achieved by using them can be increased. At present, the savings in primary energy by burning waste substances amount to about .2 percent of total national consumption. Because about half of all urban waste is dumped, it would be possible to double this figure, resulting in a contribution of 5 to 10 PJ. It has to be noted that environmental conditions have to be considered.

A potential estimate by the National Energy Research Steering Group shows that the amount of organic waste (cattle and pig manure, sewage, etc.) can be put at about 45.10 tons per year. In theory, this could produce about 10 cubic meters (30 PJ) of methane gas. However, because the waste has to be treated and the methane gas has to be used near the source of the waste, it cannot be expected that this theoretical potential will be completely achieved in the near future. The contribution by the year 2000 can be estimated at 15 to 30 PJ.

Other waste substances, such as waste wood and horticultural waste, also could be used. An inventory of agricultural waste is being made to estimate its energy potential. The problem with using such waste is that it must be done on the spot, as transport usually entails an unavoidable increase in costs.

CONCLUSION

In assessing the total contribution to be made by alternative sources of energy, it must be remembered that some of them have the same applications. This, together with the fact that there are other energy-saving techniques, means that the ultimate contribution could be lower than the sum total of all the alternative sources.

		In percentage of total demand
Solar energy	20 - 40 PJ	0.5 - 1.0
Wind energy	20 - 40 PJ	0.5 - 1.0
Energy from waste	20 - 40 PJ	0.5 - 1.0
Geothermal energy	5 - 10 PJ	0.1 - 0.2
Others	-	

The potential contribution from these sources of energy, particularly the direct application of solar energy, is higher. The National Energy Research Steering Group working group put it at 10 percent of energy consumption provided summer heat can be stored for use in the winter. However, it will be well into the 21st century before this figure is achieved.

POLICY AND DEVELOPMENT PLANS FOR ALTERNATIVE ENERGIES

Alternative sources of energy now play practically no role in the energy supplies of the Netherlands. There are no precise figures for the role they might play in the future because the various applications still are being researched and developed. Most of the applications will become competitive only when the energy price levels have increased considerably and the costs of the required installations have dropped further.

Policy therefore not only encourages research and development but aims to find the most economic application as soon as possible by means of experimental projects. The criteria used for current and new research projects are:

- The expected contribution to the energy supply.
- When this contribution can be achieved.
- The opportunities for industrial innovation.
- The expected effects on the environment and health.
- The opportunities for international cooperation (in this context the European Community and the International Energy Agency -- IEA -- are of importance).

The following sections will deal with the organization of the research on energy and the various bodies involved, and discuss the projects being conducted on alternative energies.

Solar Energy

A considerable amount of research and development work will be needed if solar energy is to be used in the Netherlands. A large number of projects have been started since 1974 with government support. In 1978, a National Solar Energy Research Program (NOZ) was launched, the principal aim of which is to introduce and develop the use of solar energy in a responsible fashion. To this end, as a follow-up to existing experiments, installations are being developed which are specially adapted to the Dutch climate and which can be produced by Dutch industry. The research will be conducted by the various research institutes and universities in cooperation with Dutch industry and the future users of the solar installations. The Energy Research Projects Office at the Netherlands Energy Research Center has been given responsibility for management and coordination of the project.

The aim of the first stage of the program, which runs from the beginning of 1978 to the end of 1981, is linked to the recommendations made by the working group. The main object of concern is to make the solar boiler ready for the market. The technical development is now so advanced that the emphasis will be placed on a number of large-scale experimental projects. In addition, studies will be conducted on the possibilities of space heating (particularly active systems), solar cooling and seasonal storage of heat.

The following table shows the allocation of the program budget:

Topic	Government contribution*
Solar boiler	5,235
Space heating	10,368
Seasonal storage	1,649
General	1,288
Unforeseen	1,610
	20,050

Thousands of Dutch guilders*

It is expected that third parties (participants, the European Community, municipal authorities and others) will contribute approximately 10 million guilders so that the total budget will amount to about 30 million guilders.

The solar boiler is expected to be the first solar energy system to be economical under Dutch climatic conditions. It has proved difficult to set up a number of large-scale experimental projects because of the poor economic viability of the systems and various non-technical problems. At the end of 1980, financial scope was created within the program to fund experimental solar boiler projects. While they are being set up and implemented, an analysis will be made of the non-technical difficulties involved in introducing solar energy.

Space heating systems will be economical only in the long term (after the year 2000). The program is therefore mainly concerned with study and research and a number of pilot projects at the moment.

Cooling and air conditioning are considered to be of minor importance in the Netherlands and no work in this area is being done under the program at this stage. However, the Ministry of Development Cooperation has commissioned the development of an absorption cooling machine based on solar energy outside the program, and a prototype will be put into operation in the Sudan some time in 1981.

Solar energy will become a considerably more important source of energy in the Netherlands if a method can be developed of storing heat generated in the summer for use in the winter. The Netherlands is participating in the IEA research program on this entitled "Energy Conservation through Energy Storage."

At the end of 1980, an extensive research project was started to complement the Solar Energy Research Program. If the results are favorable, an energy storage system will be linked to 100 homes. The storage of low-grade energy is not only important in the application of solar energy -- it also can contribute to the use of superfluous industrial heat and waste heat from electric power stations.

Wind Energy

The National Wind Energy Research Program, financed entirely by the government, was launched in 1976. The aim of the program, which was prepared by a National Energy Research Steering Group committee, is to discover how wind energy can contribute to the supply of energy in the Netherlands. Initially the program was concerned with the large-scale generation of electricity for the national grid. Data was collected, a study was made of the problems of integrating highly fluctuating wind power into the grid and it was investigated how wind turbines influence each other when they are operated in groups.

In the course of the program, which officially ends at the end of 1980, interest in the decentralized application of wind energy has increased considerably. The program therefore was extended in 1980 to cover this topic and to study the application of small wind turbines (10 to 100 KW) which have been set up near the users of the electricity, heat and/or mechanical energy they generate. The program's evaluation has been completed recently. Whatever the results, it has been decided to start a follow-up program in which industry will be involved more directly and which will place more emphasis on experimental projects and the construction of prototypes. Important research topics at the National Wind Energy Research Program are:

- The tip-vane study at Delft University of Technology, which is concerned with increasing the capacity of a wind turbine by fitting the rotary blades with what are known as tip-vanes. Laboratory experiments have shown a power increase with a factor of 2.5 to be possible. A demonstration project is being prepared.

- The wake-effect study by the Organization for Applied Technical Science, which has built a model to determine how wind turbines affect each other when they are placed close together. The experiment and calculations show that the optimal distance between the turbines is six to seven rotary diameters, and not 10 as has been assumed until now. The model is now being perfected on the basis of measurements from experimental wind turbines.

- The design and construction of a wind turbine in Petten with a horizontal axis 25 meters in diameter. This is, in fact, a construction to provide readings which will enable designers to create reliable wind turbines. The first measurements will be made in early 1981.

There are many other institutes besides those working under the program that are concerned with wind energy. Their results also will be taken into account when evaluating the potential contribution to be made by wind energy to energy supplies in the Netherlands.

The total budget of the program is approximately 20 billion guilders.

Geothermal Energy

The basic problem with geothermal energy is that, before it can be decided to exploit it, relatively expensive and highly risky exploration work has to be carried out to establish with some measure of certainty the production potential. At present, insufficient data is available to make a serious assessment of the potential and the contribution in the year 2000.

To get some idea of the potential of geothermal heat, a National Geothermal Research Program was started in 1979. Its aim is to gain as much information as possible on the presence and properties of geothermal strata and reservoirs and the heat flow 2 to 4 kilometers under the surface of the Netherlands.

Research also is being conducted into the possibility of storing heat in aquifers. An inventory is being made of suitable aquifers at a depth of 300 to 800 meters under the ground.

The program budget is Fls. 4.2 million, excluding experimental projects. The program continues officially until the end of 1982.

Energy from Waste

Research into the possibility of saving energy by recycling waste has been carried out mainly as part of the research into methods of treating waste. The disposal of urban waste is in the first instance an environmental problem. Research into the possibility of reducing the amount of waste and of reclaiming certain of its components shows that a considerable savings in energy can be achieved by means of most of the alternative disposal methods. The savings can be direct, by burning the waste or some of its components, or indirect, as a result of industry using recycled products instead of conventional raw materials.

An inventory is being taken of the results of waste disposal studies and of the methods of saving energy that have emerged in the course of the research. The inventory will be used to determine whether further research into energy saving by recycling will be worthwhile.

Other Alternatives

For reasons mentioned in the foregoing chapter relatively little attention is being paid to the other alternative sources of energy at the moment. However, developments in this field are being followed by means of international discussions and conferences. These primarily concern the use of water power, wave and tidal energy and biomass.

HOW RESEARCH ON ENERGY IS ORGANIZED

Research that is wholly or partly financed by the government is conducted by the Netherlands Energy Research Centre, the Organization for Applied Scientific Research, the various universities and industry. To coordinate the research as far as possible and ensure optimal use of the available manpower, materials and funds, the research on the various priority areas is planned as far as possible in advance and carried out in the form of national research programs. The research center, the Organization for the Advancement of Pure Research and the Organization for Applied Scientific Research are responsible for coordinating the research programs. The research center and Organization for Applied Scientific Research have set up special energy research projects offices for this purpose. These offices receive work direct from the Ministry of Economic Affairs, which consults other ministries.

The research center's Energy Research Projects office is coordinating the research programs on wind energy, solar energy and energy storage in flywheels. Whether it should be called in to manage the research on coal is now under discussion.

A separate Energy Research Projects office is coordinating the research program on geothermal energy. It also will be given the tasks of managing the research on energy saving.

Supervisory committees consisting of independent experts are appointed to assess the progress, the effectiveness and the quality of the research. The committees advise the Minister for Economic Affairs. The Energy Research Council, composed of the three parties involved -- researchers, users and industry -- has been set up to outline and coordinate the various research programs. It also evaluates progress made in general and fosters and promotes consultations between all the parties concerned.

The Netherlands Energy Development Corporation was set up in 1976 to bring new products and systems in the field of energy into the market quickly. Although the corporation is not concerned with research and development, it is very important that it cooperates with the research institutes, and similar organizations. The general aim of the corporation is to contribute to improving the energy supply in the Netherlands. It is doing so by investigating the possibilities of reintroducing coal and of saving energy in various areas.

Figure 1 gives an overall impression of the structure of energy research in the Netherlands.

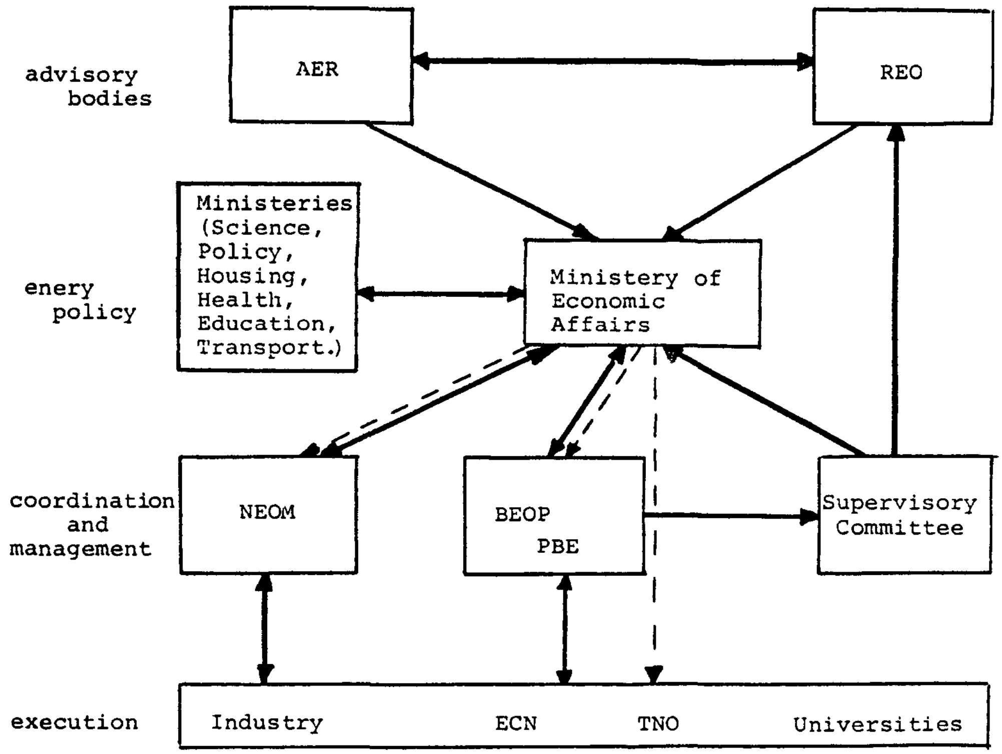
TABLE 1: TOTAL CONSUMPTION OF VARIOUS SOURCES OF ENERGY
(PJ)

	coal	oil	gas	nuclear[2]	other	total
1977	134,0	1067,7	1394,2	46,1	8,4	2650,4
1985	297,3	1524,1	1406,8	41,9	8,4	3278,5
1990	376,8	1620,4	1415,2	41,9	8,4	3462,7
2000	858,3-389,4	1787,8	1277,0	41,9-510,8	75,4	4040,4

[1] Including oil consumed in non-energy applications, excluding bunkers.

[2] Including imported electricity.

FIGURE 1: ORGANIZATIONS CONCERNED WITH ENERGY DEVELOPMENTS



Norway

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INTRODUCTION

Norway is one of the industrialized countries having the most abundant supply of its own energy resources. For a long time fuel wood was an important source of energy. But water power has also been in use throughout long ages, to power simple mechanical installations, such as grindstones and sawmills. From the beginning of this century, water power was harnessed for the production of electricity. This triggered the modern industrial development of Norway. In the course of this time, the supply of electricity has reached practically all households in the country. For large parts of our industry -- in particular the power-intensive industries -- the supply of cheap water power or hydro power has been the principal and indispensible prerequisite. In the course of the past 10 years, the deposits of petroleum in the Norwegian part of the North Sea have come to play an increasingly important role in the Norwegian economy. These deposits give added security for the country's own supply of oil.

These natural preconditions and historical developments have resulted in the fact that Norway has a higher rate of consumption of electricity than other industrialized countries (19 MWh per inhabitant). The overall consumption of energy (154 GJ per inhabitant) is, however, on the same general level as in many other West European countries. The growth in primary energy consumption for the period after 1900 is shown in Table 1.

Hydro Power

The construction of hydroelectric power plants started in a small way 100 years ago. But it was not until after the turn of the century that the first major construction projects were carried out. The development of electricity production and consumption are shown in Figure 1.

In pace with the construction of power plants, the need for power transmission increased. The initial start of pooling electric energy between several power companies for the purpose of creating a mutual power reserve and for the more efficient use of water resources took place around 1920 in eastern Norway. In the 1950s and 1960s, regional grid associations were created in western Norway, in Trøndelag and in northern Norway. As a result of integrating all the various regions of the country, these associations were integrated into the Power Pool of Norway in 1971. It is essentially the state which has constructed the large power transmission lines.

Toward the end of the 1950s a more extensive system of exchange of power was developed between Norway and Sweden and, from the middle 1970s, also between Norway and Denmark. It is the state which handles all export and import of power.

The course of hydro power development in the postwar period has been linked to an increasingly efficient technology. During the period 1960-1970 there were, for example, practically no cost increases in the development of hydro power. Improved construction operations and larger production units compensated for the general rise in costs. In the 1970s, however, construction costs rose sharply. Most of the economies of rationalization and operations of scale had by then already been obtained. Ever stricter demands for the protection of the environment and the external and internal milieux in connection with construction projects have besides resulted in higher costs.

It was clear already at an early stage that the economic value of the waterfalls was very great. For this reason, the Norwegian authorities were afraid that these waterfalls would be bought up by foreign interests.

This led to a hectic period with legislative enactments designed to secure Norwegian control of the exploitation of the country's hydro power resources. The so-called "panic laws" made their appearance as early as 1906. This legislative work culminated with the act relating to Acquisition of Waterfalls and the act relating to the Control of Watercourses in 1917, both of which, with certain amendments, still are applicable today. Together with these acts, provisions on the obligation to obtain a government concession and on concession conditions were introduced which enabled the authorities to keep development under control. In particular, the provisions concerning the reversion of waterfalls to government ownership should be mentioned. This means that the right of ownership of privately owned waterfalls reverts to the state without compensation after a period of 50 to 60 years.

The exploitation of our low-cost water power resources has resulted in major investments in power-intensive industry. This has led to the fact that we have found it profitable to use electricity for purposes where other countries largely use other sources of energy, for example ... for room heating. The development of the hydro power network also has provided the basis for a mechanical and electro-technical supply industry, both for power stations, transmission plants and consumer appliances, as well as for the equipment of power-intensive industrial production at home and abroad.

Up to the first half of the 1960s there was practically unanimous political agreement on hydro power development. Following this period, we have experienced sharp conflicts of opinion in that the issue of encroachment on nature and its environmental effects have steadily been given greater weight compared with the socio-economic value of the further development of hydro power.

In 1978, the gross product within the power supply industry amounted to approximately Nkr 7,500 million. This equals approximately 3.6 percent of the country's GNP. Investments in the same year were approximately Nkr 5,400 million, that is to say about 8.3 percent of the total gross investment in Norway. This high proportion is due to the fact that the production of power is very capital-intensive. Employment was in the region of 15,500 man-years, as against 1,677,000 for the country as a whole.

In January 1980, hydro power cost about 12 øre per kilowatt-hour, while oil-fired power is estimated at about 23 øre per kilowatt-hour and coal-fired power at about 16.5 øre per kilowatt-hour. The cost differences in real terms will be even greater because the cost of already developed hydro power is lower, while a great deal of hydro power can still be developed at lower cost than thermal power stations.

If today's production of firm power were to be replaced by oil-fired power, the consumption of oil would increase by at least 16 million to 17 million tons per annum -- a tripling in relation to today's oil consumption. If we had been obliged to base ourselves on thermal power, our total consumption of electricity would, however, be very much smaller than is the case today.

Against this background it can be said that our hydro power resources represent a considerable economic advantage compared to many other countries which have to base their production of power on thermal power stations.

Oil and Gas

In contrast to the development of hydro power and the possible utilization of new energy resources, the petroleum activities are not specially earmarked for our own energy supplies. As early as 1975, production on the Norwegian shelf was of the same order as our domestic consumption. In 1980 we produced about 2.5 times as much oil as our domestic consumption. Measured in terms of energy content, oil and gas production amounted in 1980 to respectively 23.9 Mtoe and 25 Mtoe. The production and export of oil and gas will increase further in the next few years. The development of production up to 1980 is shown in Table 2.

Coal and Coke

Today coal and coke constitute a relatively modest proportion of Norwegian energy consumption. However, at the turn of the century more than 50 percent of our energy demands were covered by coal, coke and cinders.

Compared to the rest of the world, both production and consumption of coal in Norway is almost negligible. During the past few years imports have been about .5 million tons per annum. At the same time, a certain export has taken place, especially to West Germany for fueling thermal power plants.

Other Sources of Energy

The forest has for many centuries been an important source of energy, and at the turn of the century almost half the consumption of energy was covered by fuel wood. Today, the consumption of fuel wood is approximately .5 million cubic meters, corresponding to approximately 4.3 PJ, or about .6 percent of the primary total consumption. The sharp decline which has taken place is due partly to the fact that, particularly in the cities, fuel wood proved to be too costly as regards transport, storage and consumption. We have had an increase in the price of pulp wood, while the price in real terms of oil has declined over a longer period of time and the supply situation of low-cost hydro power has been very adequate. These developments removed the basis for the Wood Chips Council, which was actively engaged in promoting the use of wood chips as a fuel during the period 1959-1962.

Apart from room heating, forest energy has in times past been of great importance in mining operations, and wood-processing and smelting industries. The smelting industry used more than 100,000 tons of fuel wood in 1977 as a reduction material in the production of ferro-silicium. Of late, the sawmill industry has become a steadily increasing user of heating facilities as a result of the transition to artificial drying and the demand for warmer work places. Given today's high oil prices, bark and wood chips have again become attractive as a fuel. Boiler installations have also been developed so that waste wood can be utilized almost as rationally as oil.

Peat has been used as a fuel in Norway for more than 1,000 years, particularly in the non-wooded coastal areas of west Norway, in Trøndelag and in northern Norway. Annual production has declined to an estimated 2,000 cubic meters, corresponding to about 17 TJ. This is due to the fact that peat has become too costly and awkward to handle in production and consumption. Today the importance of peat as a fuel is largely as a contingency fuel in case of an emergency.

ORGANIZING AND FINANCING THE SUPPLY OF ENERGY

Energy questions affect many sectors of the community and the government administration. As a result most of the other government departments also are involved in energy questions as part of their terms of reference and responsibilities. The Ministry of Petroleum and Energy, which was established in January 1978, is responsible for preparing, coordinating and furthering petroleum and energy questions and they are responsible for ensuring that other affected ministries are brought into the preparatory proceedings.

The ministry is mainly responsible for the formulation of Norwegian energy policy, including the most important aspects of Norwegian petroleum policy, and for the preparation of programs and measures which are necessary in order to implement the policy on energy both at the national and at the regional level. This includes measures which can affect the demand for energy and the supply of energy. The exploitation of our water potential and other energy sources, including the development of new, renewable energy resources, and energy conservation are important fields of responsibility. The ministry is also chiefly responsible for stimulating and promoting the research and development which are necessary to reinforce the policy on energy. In addition, the ministry is responsible for policy instruments needed in the planning and follow-up of the various sectors of the petroleum and energy policy, such as drawing up energy forecasts and cooperation on energy accounting and budgeting.

The Ministry of Finance is responsible for the preparation, coordination and implementation of the government's annual economic plans in the national budget, the fiscal budget and the revolving four-year long-term central government and social security budgets. This implies that the ministry is responsible for the adaptation of energy production and energy consumption to the overall economic activity of the country, including questions relating to prices, taxation and other charges and dues.

The Government Secretariat for Long-Term Planning and Coordination is responsible for the preparation of the government's Long-Term Program and for the coordination of long-term planning in government sectors. The secretariat is responsible for making medium-and long-term macroeconomic forecasts, which serve as a basis for energy prognoses

The Ministry of Environment has the main responsibility for overall evaluations and coordination of the management of natural resources. This also applies to production and consumption of energy. Studies and the administrative handling of important matters in this field are carried out in close cooperation between the Ministry of Petroleum and Energy and the Ministry of Environment. As part of this work, accounting and budgeting systems have been prepared in respect of energy resources.

The Ministry of Industry has the general administrative responsibility for the dominant group of energy consumers -- industry. It is therefore important to ensure that industrial considerations are taken into account when formulating energy policy. This applies both to production of equipment for such energy plants as power stations and offshore installations, energy consumption and industrial exploitation of the Norwegian petroleum deposits.

The Ministry of Local Government and Labor is responsible for improved methods of energy conservation in buildings.

Research in connection with the production and consumption of energy is being conducted in a number of institutions under the Ministry of Church and Education. Of importance here are technological and economic research into the consequences of energy production and consumption, which are significant fields of research within the natural sciences, medicine and the social sciences.

Under the Ministry of Consumer Affairs and Government Administration, the Price Directorate is responsible for administering the price regulations to which energy products, with the exception of electricity, have been made subject.

The price authorities are cooperating with the Norwegian Water Resources and Electricity Board (NVE) on a system with semi-annual reviews of prices and price developments for electric energy and on specific price questions.

Through the Directorate for Construction and Government Property, the ministry is responsible for the efficient use of energy in government buildings. Work is going on through the external consumer apparatus to spread information on energy conservation and energy consumption in households and through consumer goods to the consumers.

The Ministry of Agriculture is engaged in promoting the use of fuel wood for energy purposes. Various research projects are underway in this field. The ministry has at its disposal appropriations for the felling of deciduous trees and for transportation of timber subject to specified conditions.

Through the responsibility which the Ministry of Foreign Affairs has for the formulation, coordination and implementation of Norwegian foreign policy, the ministry takes care of the foreign policy aspects of Norwegian energy policy. At the multilateral level, the Ministry of Foreign Affairs' field of responsibility includes the International Energy Agency (IEA) in cooperation with the Ministry of Petroleum and Energy, and energy questions within the United Nations.

In addition, several other government departments are responsible for various aspects of energy management.

THE NORWEGIAN WATER RESOURCES AND ELECTRICITY BOARD'S ROLE AND STRUCTURE

Norway's Water Resources and Electricity Board (NVE) was established in 1920, and separate government administrative agencies within the water resources and electricity supply administration were gathered under the board of the NVE. The duties of the NVE have changed both as to content and scope since 1920. However, the division of responsibilities in relation to other government agencies at the directorate level has been kept unaltered.

The NVE is organized in four directorates: the Water Resources, Electricity and Administration directorates, as well as the Directorate for the State Power System. The NVE is under the direction of the board of the NVE and a chief executive of the NVE.

The NVE's Duties

Within the Electricity Administration, the NVE assists the ministry with the following tasks:

- Forecasting the country's needs for electric power.
- Preparing main plans for the country's power supply apparatus and ensuring planning cooperation between the construction enterprises.
- Preparing general plans for the proper disposal of the remaining large sources of water power for hydroelectric supply purposes.
- Acting as the advisory agency in all questions relating to power supplies.
- Being responsible for the handling of matters relating to government concessions and expropriations for power installations.
- Being responsible for the control and supervision of electric installations, materials and apparatus.
- Being responsible for the management of the country's power supplies in emergency situations.
- Ensuring that the advantages of pooling all the country's power supply are properly utilized.
- Being responsible for the exchange of power and participation in the cooperation on power supplies with other countries.
- Being responsible for the planning, construction and equipment of the state power plants and the main transmission network.
- Being responsible for the operation of the state's power production and transmission systems as well as the disposal and sale of power from government power plants.

Within the management of watercourses work is being carried out on the following assignments:

- Monitoring the general public's and the state's interests in watercourses.

- Acting as the ministry's advisory and coordinating body in watercourse matters.

- Being responsible for hydrological, glaciological and geodetic surveys and measurements in connection with watercourses.

- Handling and submitting recommendations on the regulation of private enterprise, watercourses and regulatory concessions.

- Exercising control and supervision of plants in and above watercourses, with the exception of effluent treatment plants and irrigation systems.

- Preparing contingency measures and acting as advisors for disasters occurring in watercourses.

- Being responsible for flood warning as well as the planning and construction of flood control installations.

- Taking the initiative in the care of the countryside in connection with the construction of hydro power installations.

- Collecting payment for government concession dues to the state and the local authorities and distributing municipal dues in connection with regulatory matters.

THE RESPONSIBILITIES OF THE STATE, COUNTIES AND MUNICIPALITIES

By the end of 1978 there were 489 units within the power supply system -- 293 electric power plants, 74 wholesale supply plants/power companies, 87 industrial power plants and 34 farm or rural local community plants. Out of a total maximum power station capacity of about 17,500 MW, the capacity is distributed as follows:

- The State Power System, 25.8 percent.
- Local government power companies, 53.6 percent.
- Privately owned power companies, 20.6 percent.

More than two-thirds of the electric power plants have fewer than 5,000 subscribers and together they only supply approximately 25 percent of the entire country's subscribers. About 60 of these smaller electric power plants are privately owned, while the rest are owned by the municipalities and/or county municipalities. The state does not participate in the retail delivery of power for supplying the general public. The power-intensive industries were originally based on sources of water power which the enterprises themselves harnessed. In due course a steadily increasing number of enterprises have become buyers of power, principally from the State Power System.

The entire country is linked together in a continuous transmission network, even if certain parts of it have as yet a lower transmission capacity than is desirable.

The individual power plants feed their power into the network, while at the same time the electric power plant which is to receive the power takes out a corresponding amount at a central point within its own area. The transmission capacity of the entire network is placed at the disposal of all users, regardless of the transmission line distances used. This is settled through an arrangement for the use of the main transmission system.

In addition to acting as a common transportation system, the main network also makes it technically possible to operate all power stations as a unified production system. The power plants delivering power into the network may have production conditions varying in magazine capacity, machine capacity and hydrology. These differences can be used advantageously by interconnecting the power stations in such a manner that the system provides a greater production of firm energy than the sum of what the individual stations are able to produce on their own. This difference is called optimization gain. Such a cooperation on production has been established on a voluntary basis through the Power Pool of Norway.

Local Energy Planning

Most of the production, transmission and distribution of electricity is conducted under public auspices with the State Power System by far the largest producer and owner of approximately 80 percent of the transmission network. The distribution of electric power for general public consumption is undertaken substantially by the municipal, intermunicipal or county-municipal plants. There are great variations in prices and other delivery conditions for electric power.

The municipalities and county municipalities have, through their enterprises within the energy supply system, acquired extensive experience regarding a substantial part of our energy supply. These institutions also are showing an increased interest in district heating production and district heating supplies based on, for example, forestry waste, industrial and household waste, and the utilization of waste heat.

Also on the consumer side, the municipalities and county municipalities are showing active interest. In certain places, for example, guidance is given on the choice and use of electric appliances, and heating and ventilation equipment. Information campaigns have been undertaken to influence the public's attitude. The possibilities for energy conservation in their own local government buildings are being investigated. In many places special energy committees have been established to investigate the possibilities of conserving energy.

In Norway, there are great variations between the counties and even greater differences between the municipalities with regard to geographical size, number of inhabitants, population settlement patterns, industrial structure, economy and the extent and the standards of the municipal administration. Thus there will be great differences in the basis and opportunities for the individual local government authority to influence production and consumption of energy within its own area.

Local energy planning may take two partly separate forms:

- An energy plan, action program or the like is prepared for all or part of the county municipality or geographical area of the municipality.

- The effects on the energy sector of specific objectives or measures are drawn into other planning operations.

It should be possible to use both these forms. To get underway with the work on local energy planning, a possible procedure may be to prepare energy forecasts for the expected development of the community at large. On the basis of these prognoses, a brief program of action may be prepared, where a study is submitted on how the consumption of energy can be covered in future. Regarding the larger cities, it might for example be appropriate to work out thermal schemes. For major construction projects, as for example municipal or county-municipal buildings, industrial areas, sports facilities and new housing areas, consideration should also be given to the consequences of future consumption of energy in the form of consequence analyses.

Financing the Supply of Energy

The State Power System's investments in the electric power sector are wholly covered by appropriations from the fiscal budget. The local electric power plants' investments are covered by the plants' own budget. Local investments are financed by means of loans, government support and use of local capital resources. Table 3 shows how the supply of electric power has been financed during the years 1972-1979.

It is important that the supply of electric and thermal power is considered as a whole. This is due to the fact that the heating needs may be covered in different ways, by district heating based on local energy resources, such as wood chips, bark and waste heat or heat pumps and energy recovery plants on a larger scale. Larger thermal power plants will hereafter be sought and adapted to the same financing channels as the electric power supply. Loans for such plants will thus, to a large degree, be coordinated with power projects. The question of how and to what extent such financing arrangements can be adapted to the credit budget will be considered in connection with the annual national budgets.

There are also special arrangements relating to energy conservation loans to industry and use of waste for energy purposes. During the period 1976-1979, approximately Nkr 145 million was granted in loans and about Nkr 120 million as loan guarantees, totaling approximately Nkr 265 million. Total investments in such measures are calculated at approximately Nkr 415 million.

RENEWABLE SOURCES OF ENERGY

Until petroleum production on the Norwegian continental shelf got underway, our energy production consisted largely of hydro power. As petroleum production increases, the share of hydro power in our energy production will decrease. Calculated on the basis of energy content, the hydro power production amounted to roughly 30 percent of our total gross energy production in 1977. The remaining energy production came chiefly from oil and natural gas. On the basis of the estimates made for petroleum production in the 1980s and the proposal put forward for the development of hydro power, hydro power production will fall to 10 to 15 percent of our total gross energy production toward the end of the 1980s.

Because the bulk of our petroleum production is exported, hydro power has an important bearing on our domestic energy consumption. In 1977, hydro power amounted to 56 percent of utilized energy consumption. According to the forecasts worked out for energy needs in the 1980s, hydro power's share of utilized energy consumption will not be changed to any marked extent in the coming years.

It should be one of the aims of the future energy system to increase the share of renewable energy sources. Regard for better use of resources, for the environment and for reliable supplies render it desirable to reduce dependence on finite stock resources. It is therefore natural to consider other energy sources such as sun, wind, ocean waves and biomass in addition to hydro power.

However, there are many problems of a technical, economic, organizational and environmental nature to be solved in connection with such a readjustment. In the immediate future (five to 10 years), other sources of energy such as wave power, bio-energy, solar heating and wind power in Norway are hardly likely to be able to compete in terms of cost with today's sources of energy. But in the longer term the situation may change for one or more of these sources.

An energy system which is mainly based on renewable energy sources can entail considerable changes in the organization of production, in maintenance and the pattern of consumption. It may entail a new set of priorities for the general benefit of the community and competition with other activities may arise.

All readjustments of energy systems take time. Decisions made today will have effects in 10 to 30 years. If the energy system of the future proves more costly than today's alternatives, a readjustment would be even more difficult to carry out. These problems must, however, be weighed against a future situation where a failure to readjust may lead to serious supply crises due to shortage of energy.

Only a small part of nature's total energy streams can be utilized. The limiting factors will be economics, degree of effect, usable area and environmental considerations.

On the basis of today's standard of technology and knowledge of the energy resources at the national level, bio-energy, waves, solar heating and wind seem to be the renewable energy sources likely to be utilized in Norway, in addition to hydro power, from about the end of this century.

Bio-Energy

Norway's annual yield of timber is about 18 million cubic meters. Of this, about 12 million cubic meters is used in production, and the surplus is therefore about 6 million cubic meters. If we include branches, tops and roots, the yield can be estimated at 25 million to 30 million cubic meters annually. The theoretical energy content in the total yield amounts roughly to 200 PJ or approximately 4.7 million tons of oil equivalents.

Most of the timber that is utilized is used for industrial purposes. This gives about 350,000 tons of bark and a corresponding amount of waste chips annually. A fair portion of these resources are put to use by the industry itself.

Measured by their dry weight, the branches, tops and roots constitute about half of a tree's biomass. The interest in forest yield as energy has therefore largely been directed towards these marginal timber reserves, such as tree stumps, felling waste and thinnings.

Utilized for energy purposes, the biomass can be burned directly or transformed into liquid fuel or gas. The solid forms, such as fuel wood, chips and charcoal, seem to be of most immediate interest. For use within the transport sector, transformation to liquid fuel, such as methanol, has interesting possibilities.

Today, biomass in the form of wood represents about 1 percent of our energy production. Studies show that, on an economically profitable basis, it is possible to extract marginal forestry products corresponding to an energy amount of about 25 PJ/years -- close to 3 percent of the gross energy production today.

How much of the rest of the yield it is possible to make available for energy purposes will depend on the raw material requirements of other timber customers. The annual figure of 12 million cubic meters for timber used in production can be increased in the longer term to about 15 million cubic meters even with traditional forestry techniques.

How far biomass will be competitive in the future with other forms of energy will depend on the form and way in which it is utilized, and the costs connected with the exploitation of the resource. In the short term, the greatest possibilities lie in utilizing chips or briquettes in larger district thermal plants or in smaller individual units. In the longer term transformation to charcoal will be an alternative. Based on the price for pulpwood of birch, fuel wood, according to estimates made in 1978, would cost in round figures 10 øre per kilowatt-hour. Cord wood delivered to the consumer is dearer, however, and costs about 20 to 40 øre per kilowatt-hour. In the case of transformation into charcoal, the costs were estimated to be 15 to 30 øre per kilowatt-hour, half of this being the raw material price.

According to the Norwegian Marshland Reclamation Society, Norway has peat fuel resources of about 5,000 million cubic meters of raw peat. The annual yield is estimated to be about 5 million cubic meters. The energy content of the country's peat deposits is considerable, but practical and environmental conditions will limit its exploitation.

In addition, various types of organic and other waste material represent considerable amounts of energy. Because many types of waste occur in widely dispersed areas, it also would require a relatively large amount of energy to utilize them. It is therefore only feasible to make practical use of some of these.

Wave Energy

The total energy content of the ocean waves that roll in annually toward the Norwegian coast is estimated to be in the region of 2,100 PJ or 600 TWh. Compared with solar and wind energy, wave energy is more concentrated. As an annual mean, the effect is estimated at about 24 KW per meter of wave crest outside the skerries. Only a fraction of the theoretical energy content, however, will be utilizable.

The wave energy is greatest in winter and less variable than, for example, wind energy. Extensive use of wave power, however, necessitates reserve power in periods with little wave action. Any wave power plant would therefore have to be coupled with the hydro power system.

If we assume that 5 to 10 percent of the coastline can be utilized in the future for wave power production and that the wave power plants can transform 10 to 30 percent of the energy in the waves to electricity, this would equal an electricity production of 3 to 18 TWh per year.

It is difficult to say anything regarding the costs involved in producing electricity from wave power. Economic estimates for various projects give costs in the region of 20 to 100 øre per kilowatt-hour. The most comprehensive cost estimate so far has been carried out for the buoy project and suggests costs down to 20 to 30 øre per kilowatt-hour. Cables to the shore, coupling to the grid and operation and maintenance costs are not included.

In the field of wave power research, Norway is well to the fore internationally. The Norwegian wave power projects start from two physical basic principles. One is based on point absorbers and is being developed by the Norwegian Institute of Technology, where studies are being made of buoys in resonance with the waves, and by Kvaerner Brug, where work is being done on a system based on an oscillating column of water. The project at the Central Institute for Industrial Research is based on the fact that waves can be focused.

Buoys that oscillate in resonance with the ocean waves constituted the first Norwegian wave power project, and this is so far the one that has progressed furthest. As the buoys swing in correspondence with the sea waves, they can draw energy out of the length of a wave crest which is considerably greater than the buoy's cross section. It is from this that the term point absorber is derived. Each buoy may be assumed to have a diameter of about 8 meters and normal wave conditions provide for an optimum distance between the buoys of 50 to 100 meters. According to the calculations worked out, a wave power plant which is to produce 1 TWh per year net will consist of about 1,000 buoys and require an area of 5 to 20 square kilometers.

Instead of an oscillating buoy, wave energy can be transfered to oscillating movements in a column of water. The transformation of the wave energy can conceivably be effected in a concrete tower standing on the sea bed. As in the case of the power buoy, many different forms are possible. This project is still at an early stage of research.

In the same way light can be focused with the aid of a burning-glass, ocean waves can be focused with the aid of an "ocean wave lens." The lens may be imagined as consisting of a long series of steel containers sunk to a depth of 30 to 50 meters below the surface of the sea. The ocean waves can then be gathered in toward a focusing point where the waves can be more than 10 times greater than the swell reaching the lens.

At the focusing point, a funnel-shaped chute, for example, is envisaged leading the waves up into a high basin. The potential energy the water in the basin has then can be used as in an ordinary hydro power plant. Other possible ways of transforming wave energy into electricity also are being considered. The lens elements could be placed in a 10 kilometer row. With the basin placed to give a 50 meter drop, a plant of this nature could, in theory, provide up to .7 TWh electricity production per year.

These projects are proceeding with support from public funds, approximately Nkr

33 million having been spent so far. All the projects are still at the research stage and it is too early to say whether they will prove economically profitable. If they prove to be profitable, a wave power plant could come into operation in the 1990s.

Solar Energy

At 60 degrees latitude the mean solar radiation is 100 watts per square meter on a horizontal plane so that the annual mean for solar energy is about 900 KWh per square meter. Of this, just less than half is direct radiation while the rest is sunlight spread from clouds and particles in the atmosphere -- diffuse radiation.

By comparison, it may be mentioned that the mean solar radiation at the equator is two to three times greater than, and at 40 degrees latitude about twice as great as, at 60 degrees latitude.

Solar energy, through the use of solar panels (active solar heating) or the building's design and directional orientation (passive solar heating), can be used for heating and, through the use of solar cells, for the production of electricity. The cost of electricity produced by solar cells is too high to be competitive in Norway.

At the present time, solar energy is primarily of interest for heating buildings, for hot water for dwellings and for low-temperature processing water in industry. The greatest amounts of energy are available at a time of year when the need for domestic heating is least. If solar heating is to be a good alternative, it should be possible for the energy to be stored from the summer until the winter months. However, the fact that storage facilities are somewhat limited does not mean that solar heating is entirely without interest. Experiments have demonstrated that even if the storage facilities are limited to leveling out over a period of one to two weeks, solar heating can cover 30 to 50 percent of the heating and hot water needs in dwellings.

The introduction of solar heating systems will primarily be of interest for new buildings. Norwegian producers of prefabricated housing already are marketing solar heated houses. Today, housing is being renewed at a rate of 35,000 to 40,000 dwelling units per year. At the same time, about 15,000 dwelling units fall into disuse. We have roughly estimated that this trend will continue until the turn of the century, and after that the annual net number of new dwellings will be less. Within a time perspective of about 40 years it may be possible to cover some of the space and water heating requirements of a considerable portion of the total housing with solar energy. The increase in energy prices will naturally be able to make solar heating a profitable proposition for existing housing also.

Given these premises, it is expected that about 60 percent of all buildings in the year 2020 will have been constructed after 1980. Due to energy conservation measures, the consumption of energy will probably be less for the new buildings, if we do not allow for any particular increase in floor space per housing unit and altered patterns of energy consumption. While today's energy consumption for the heating of buildings is in the region of about 135 PJ (37 TWh), a 60 percent increase in housing is expected to lead to an increase in energy consumption of about 50 PJ, or about 40 percent.

On this basis, the following upper limits can be estimated for the use of solar energy in the next 40 years in Norway:

- With seasonal storage: about 30 to 60 PJ. This covers a major share of the heating requirements in new housing plus some hot water and heating for some of the older dwellings.

- Without seasonal storage: about 15 to 25 PJ.

With today's technical solutions, the cost of heating in a Nordic climate is about 30 to 50 øre per kilowatt-hour of thermal energy. The cheapest solution appears to be larger solar heating systems for group housing or larger buildings. The cost of energy also will naturally depend on the depreciation time and calculated interest, so that it is seldom possible to compare the different price estimates directly. At present, the cost of solar energy in Norway is two to three times higher than heating from conventional sources of energy.

Wind Energy

On average, the wind strengths are greatest along the coast and it is windier in winter than in summer. The seasonal variations are greatest for the areas from Trøndelag and northwards. Along the coast, the typical wind speed at a height of 10 meters above ground level is about 7 meters per second, which corresponds to a theoretically usable effect of .13 KW per square meter vertically to the direction of the wind. Inland there is too little wind energy for practical purposes. Because the wind energy varies greatly in the course of the year, to make any extensive use of it would require its being coupled with an easily regulated source of energy, if large-scale installations for energy storage and reserve capacity are to be avoided. Wind power therefore is well suited for use in conjunction with our hydro power-based electricity supply system.

The energy potential for wind has only been partly charted and therefore only can be estimated with a large measure of uncertainty. Various estimates suggest a theoretical energy potential in the region of 200 to 600 TWh per year for the belt between 50 and 150 meters above ground level. Only a small amount of this can be used in practice.

A wind power plant may consist of an array of wind turbines. A power plant with, for example, 12 wind turbines about 100 meters high, each of 4 MW maximum rated power, may be assumed capable of supplying about .1 TWh electric energy per year. With the building of one to four arrays of wind turbines like this per year after 1990, it ought to be possible to estimate the energy contribution for wind power in the year 2020 at 3 to 12 TWh annually.

The scale of such a wind power development is limited, however, by the number of possible locations. A plant with 12 windmills requires 25 square kilometers and restricts the use of the area for other purposes.

The cost of energy is very dependent upon the size of power units and wind conditions. For small windmills under 40 kilowatts, such as are available on the market today, the cost of production ranges from 30 to 50 øre per kilowatt-hour in places with average winds of 5 to 6 meters per second. For larger units, the energy cost is estimated at 10 to 30 øre per kilowatt-hour. This cost should be compared with distributed electricity wherever wind turbines are close to consumers and deliver an appropriate voltage -- which is the case for small units. Larger units must have their generating cost compared with the appropriate point in the grid. In this way economies of scale in the mass production of smaller units may outweigh the economies of larger units farther away from consumers.

Overall Assessment

Table 4 contains an illustration of possible usable energy for renewable energy sources, apart from hydro power, around the year 2020, provided there is a satisfactory technical, economic and environmental development of these sources.

Calculations and estimates of the demand for energy at the turn of the century seem to indicate that it will be necessary to have an energy production in the region of 1,000 PJ or about 23 million to 24 million tons of oil equivalents. If we allow for a gradually more effective use of energy, for example, perhaps a gross energy production of 1,000 PJ also would be representative for 2020. On the basis of such an assessment, renewable energy sources, other than hydro power, would at the maximum be able to contribute 10 to 25 percent to energy supplies in 2020. Including hydro power, the share of renewable energy sources according to this illustration would amount only to half of the energy production and there will continue to be serious pressure on the finite stock resources of coal, oil, gas and uranium.

Other energy sources than those which have been mentioned (such as geothermal energy, temperature differences in sea water and tidal differences) do not seem, in the light of our present knowledge of technology and energy potential, to be capable of being used in Norway.

A switchover to the comprehensive use of renewable energy sources is dependent upon many still unknown factors:

- Technical development: There is still a possibility of improvements in techniques already known or completely new solutions.

- Economic premises: Today most renewable energy sources, other than hydro power, necessitate an energy price considerably higher than the price for energy from conventional sources. This is largely due to the cost of investment. In competition with non-renewable energy sources the future development of prices will probably be to the advantage of the renewable energy sources.

- Environmental considerations: We now have considerable insight into the environmental consequences resulting from conventional energy sources. Regarding most of the new energy sources, there is much less knowledge of the possible environmental consequences.

- Integration in the existing energy system: To ensure stable supplies of energy the total energy system must be capable of leveling out variations over shorter and longer periods of time where wave, solar and wind energy are concerned. A high percentage from hydro power with good possibilities of easy regulation and from bio-energy will therefore be necessary.

- Need for political steering: Continued research on and development of renewable energy sources will have to take place with significant public support. This will have to be weighed against other public tasks. The authorities also will have to decide on the priorities involved when there are conflicts of use between energy production and other activities.

- Time perspective: Integration in new energy systems requires time. For example it appears that countries which have given high priority to nuclear power, even after 25 years of commercial development, only cover a small share of the total energy consumption with nuclear energy.

A provisional conclusion therefore is that if these different limitations on new and renewable energy sources do not prove to be too insuperable, by about the year 2020 it should be conceivable, for example, to cover up to about 10 to 15 percent of Norway's energy supplies, or 100 to 250 PJ, from bio-energy, and wave, solar and wind energy.

ENVIRONMENTAL CONSEQUENCES OF ENERGY SYSTEMS

All production, transport and consumption of energy affects the environment. Due regard for the environment will be important in the planning, production and use of energy for various purposes in the community.

It is often difficult to weigh the desire for the benefit dependent upon an increased supply of energy against the consequences this has for the environment. It can be difficult to measure in terms of money the value of unspoilt nature and a clean environment for today's and future generations. In several fields we lack the knowledge to be able to predict the consequences of long-term effects of encroachments on nature and of pollution. It is often easier to estimate the value of the benefits we can attain as a result of the energy that is produced.

Hydro Power

The watercourses represent an important resource in more connections than that of power production. The localities near the watercourses are generally the most productive for flora and fauna. The watercourses are production areas for fish, they are drinking water sources, they carry away and degrade pollution released in them and, in some cases, they are traffic arteries. Traditionally the watercourses have been decisive for the localization of population settlement and economic activities. The watercourses with waterfalls, rapids and lakes are also particularly attractive parts of the countryside.

The most important environmental effects resulting from hydro power development are caused by the changes made in the natural course of the watercourses and by constructional encroachments. The changes primarily consist of reservoirs used for regulating purposes with dams and intermittent unsightly draining of the areas affected and occasionally greatly varying water levels, and of permanent or seasonal changes in the flow of water in the rivers.

The constructional encroachments include dams, borrow pits, rock-spoil deposits, roads and power lines.

Hydro power development very often causes changes in the hydrology, water quality, ice conditions and the transporting and deposit of sediments in a watercourse. This can lead to changes in the local climate, the groundwater level and riverbank and lake shore conditions. Such changes in the physical environment will cause changes in the conditions governing the living environment on land, including plant, animal and bird life. The regulation of watercourses also usually causes harm to fish and other aquatic life to a greater or lesser degree.

The development of hydro power also entails competition with other user interests in the watercourses, such as nature conservation, outdoor life and fishing and hunting.

As greater importance has been attached to environmental values in recent years, hydro power development has been carried out with more consideration for the environment. It is also more often the case that a government concession is not granted or that parts of a watercourse especially worth preserving are excepted from power construction projects. The construction of reservoirs is to an increasing extent concentrated in one or a few places within a particular area. The regulating measures are often restricted for environmental reasons. To avoid conditions that might cause pollution and to safeguard water supply and fishing interests, certain minimum flows of water and other measures are prescribed for the rivers. The means of controlling the reservoirs are often adapted to make allowances for a rapid filling up of the reservoirs when winter is over and for fish conservation, icing, water requirements and scenery in the lower reaches of the river. In the case of future power construction projects, the need for complete water utilization plans will come even more strongly to the fore. Regulating mechanisms and control regulations will to a greater degree have to be adapted to the requirements of a number of user interests in the watercourse. It is reasonable to assume that by means of effective measures we can more easily than previously improve the conditions for a number of interests.

The government intends to develop the remaining hydroelectric resources according to a coherent plan. The rivers with insignificant or small user interest which at the same time offer the best economic returns will be developed first. Of the total resource of 170 TWh average production, the government regards 125 TWh as a suitable illustration of the ultimate limit to development. Above this, the watercourses with a high degree of user interest and potential for conflict with energy development, as well as the most costly projects, will be used for other purposes.

Other Renewable Sources of Energy

Direct exploitation of biomass in the form of timber and other plant material for energy purposes will lead to the release of gases in the atmosphere and the formation of ash in connection with combustion. If the replacement is as great as consumption, the release of carbon dioxide will cause no problems, since the intake of carbon dioxide will then be equal to the amount released.

The ash is alkaline and will not cause any special environmental problems if it is returned to the place of growth. Growth of biomass will require areas of between .1 and 1 square kilometer per gigawatt-hour of the heating it can provide per year, depending on the method of cultivation.

Our knowledge of what sort of pollution occurs when biological material is directly used as fuel is deficient. Using wood as fuel has the advantage that the release of sulfur dioxide is small, while the formation of nitrogen oxides is about the same as for coal and oil firing. In large and effective combustion units equipped with purifiers the total release of pollutants probably will be less than for similar oil- or coal-fired installations. If wood is used as fuel in small stoves and fireplaces, it can, however, be assumed that the release of soot and tar substances may to a considerable degree exceed the release from similar coal- or oil-fired installations.

Transforming biomass by fermentation to methane, biogas or methanol and the use of timber for charcoal will not cause much pollution because the exhaust gases from the production process will be purified. Combustion of gas, methanol and charcoal produces nitrogen oxides corresponding to direct combustion of the biomass.

Wave power stations conceivably can be built in accordance with various principles, and the environmental effects to some extent will be dependent on which technical solution is adopted. All wave power stations are intended to extract average reduction of the wave height on the leeside of the wave power station as compared with its original state. The focusing type of wave power station will concentrate the wave height in toward a point on shore, but reduce the waves on both sides of this point. On the windward side of the wave power station the waves also may be altered, because some of the waves are reflected, and the sea becomes choppier. A wave power station may have effects on fish spawn and larvae. It will be necessary to impose restrictions on fishing and maritime traffic for reasons of safety.

A focusing power station will require a safety zone around the point where the waves are collected. Generally, safety zones for wave power stations equivalent to 5 to 20 decares per gigawatt-hour are required, being on the same scale as dammed areas for hydro power.

The greatest effect that wind power has on the environment is related to its need for space and its visual effect. Around large wind turbines it is necessary to have safety zones of several hundred meters to reduce the risk from a fracture of the rotators or icing on the vanes. This ground nevertheless can be used for agriculture. It can be of practical interest to build wind turbines with an annual production of from .1 GWh to 30 GWh. The space required per gigawatt of annual production will be approximately 5 decares for the building site and 200 decares for safety zones for the largest wind turbines. The large wind turbines will dominate the landscape, and it would be better to site them along the coast or out at sea.

If the wind turbines are situated in previously untouched natural surroundings, the construction of approach roads and power lines may have the same sort of effect as in the case of hydro power development. The turbines are not expected to cause any real ecological disturbances as long as they are not situated in bird migration zones. Their noise may be a local problem, but because of the safety zones it hardly will be of any considerable significance. Large wind turbines, especially with metal vanes, may cause disturbances in aircraft telecommunications and should not be situated under or near flight corridors. Radio-based communication systems also may be disturbed. It can be assumed that such wind turbines may have disturbing effects on shipping in special cases, and this circumstance must be taken into consideration in connection with the location of a large number of wind turbines along the coast. Outside the safety zones that presumably will be established, radio or television disturbances are hardly likely.

The space required for the use of solar energy for heating will be of small significance, because solar panels usually will be placed on the roofs of the buildings to be heated. In the case of short-term storage of solar energy, the space required for thermal storage will not present any great problem either. With passive solar heating, the building is designed to receive solar energy efficiently and will not use extra building ground. As with active designs, however, restrictions will have to be laid on shading. On the other hand, thermal storage of solar energy from summer to winter will require a cubic space equal to that of the building that is to be heated. If we assume a height of 2 meters for the storage tanks, this will amount to 2 decares per gigawatt-hour for thermal storage. Generally speaking, it is intended to place energy storage installations inside the buildings or underground.

Electricity production from solar energy requires far greater solar catchment space than an installation that simply absorbs solar heat. An annual production of 1 gigawatt-hour will require 10 to 20 decares of solar cells. Solar cells for electricity production also can be combined with thermal catchment and will require less space per gigawatt-hour than the electricity production alone.

As solar radiation is distributed over the whole country, there scarcely can be any advantages from centralized electricity production from such cells. Disputes over land should be avoidable.

The use of solar cells will have little direct effect on the environment. Production of the cells may, however, produce effects of the same type as other industrial production.

Power Transmission Lines

The effect on the landscape caused by the power line tracks may be great, especially in untouched natural surroundings, flat, open countryside and rural settlements. Below the tree line the choice of route and the right type of mast can somewhat reduce the visual nuisance; for example, it is now possible to use wooden masts even with high voltages.

The power line tracks impose restrictions on the use of large areas. This is of special significance for forestry, whereas agriculture is less affected.

A properly cultivated power line track through forest may -- in the same way as other openings in the forest -- have a beneficial effect on some animal species, but also may block the migratory paths of the deer family. Swans and other large birds are likely to fly into power lines and be killed.

The choice of route is important. Different and often conflicting factors must be weighed in the process of planning and negotiating government concessions for power lines. In the course of construction, cross-country vehicles often are used. Especially in high-mountain country the transport roads can occasion an undesirable fragmentation of continuous natural areas, and the use of cross-country vehicles may inflict damage on the vegetation which may take several decades to repair. The use of helicopter transport can reduce such damage.

End Use of Energy

The effects of the end use of energy depend not only on how much energy is used but also on which forms of energy are utilized, how the energy is used, and what it is used for. Over a period of time the pattern of consumption will change so that the environmental effects also will be different. These are matters that the authorities can influence by different measures.

Through the energy policy pursued, price regulation and other energy conservation measures, the environmental effects can be restricted. By investing in decentralized energy installations such as thermal centers or small combined electricity and district heating plants, and by locating them satisfactorily, a better use of the resources and a better dispersion of the environmental effects can in some cases be attained. A decentralized energy supply also will reduce the need for long distance transmission lines. Finally, the use of a more varied set of forms of energy could reduce the dimensions of the individual elements affecting the environment, so that nature's self-purifying capacity will be better able to neutralize the ill effects.

Proper consideration for the environment may call for specific solutions in both what we use the energy for and how the energy supply is organized.

TABLE 1. PRIMARY ENERGY CONSUMPTION IN NORWAY 1900-1978

Year	Coal and coke million tons	Oil and oil products million tons	Wood and peat million cu.m	Hydropower TWh	Total Mtoe	Total PJ
1900	1.93	0.040	5.90	-	2.5	108
1910	2.65	0.065	5.90	1.2	3.1	134
1920	2.32	0.086	6.15	5.0	3.3	141
1930	3.48	0.270	6.00	8.7	4.6	195
1939	4.50	0.680	6.00	10.9	5.9	251
1950	1.74	1.270	5.25	16.7	4.9	209
1960	1.17	3.240	3.20	31.0	7.3	311
1966	1.30	4.902	2.17	48.0	10.2	438
1976	1.43	7.414	0.67	75.5	14.9	636
1978	1.26	8.497	0.67	77.7	16.0	685

Sources:

1900-1966: Report on Norway's energy supplies. Annex to Report no 97 to the Storting for 1969-70 on energy supplies in Norway in future.

1976: Energy statistics 1970-77, table 2, net domestic supplies.

1978: Provisional figures.

TABLE 2. PRODUCTION OF OIL AND GAS ON THE NORWEGIAN CONTINENTAL SHELF

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Oil, million tons	0.3	1.6	1.6	1.7	9.3	13.6	13.4	17.2	18.2
Gas, thousand million N cu.m							2.5	13.4	20.8
Total, million tons oil equivalents 1)	0.3	1.6	1.6	1.7	9.3	13.6	15.6	28.9	36.4

1) 1000 million N cu.m gas is calculated in the total as equalling 0.874 million tons oil equivalents.

TABLE 3. FINANCING OF ELECTRICITY SUPPLIES
MILLION Nkr 1972-79, CURRENT KRONER

	1972	1973	1974	1975	1976	1977	1978[1)]	1979[1)]
Loans abroad	376	380	245	440	880	1 450	2 437	2 780
- direct						703	502	596
- via Municipal Bank						747	1 935	2 184
Domestic bond loans (§15)	265	347	681	657	641	150	0	0
Loans in Municipal Bank	99	104	121	150	200	220	198	162
Government aid	36	37	31	44	48	70	98	100
Self-financing and loans from local banks etc.	598	582	480	686	432	957	999	918
State Power System	490	515	686	934	1 369	1 671	1 768	1 840
Total	1 864	1 965	2 244	2 911	3 570	4 518	5 500	5 800

1) Provisional figures
Source: NVE

TABLE 4. ILLUSTRATION OF POSSIBLE USABLE ENERGY FROM OTHER SOURCES AROUND THE YEAR 2020

	Total	Including elec. power	
	PJ	PJ	TWh
Biomass	50-100	?	?
Waves	10- 65	10 - 65	3 - 18
Sun	30- 60 1)	0	0
Wind	10- 40	10 - 40	3 - 12
Sum total, in round figures	100-260 2)	20 - 100	6 - 30

1) 15-25 PJ without seasonal storage

2) 85-230 PJ without seasonal storage for solar energy

TABLE 5. NORWAY'S DIRECT GROSS ENERGY CONSUMPTION, PAST AND FUTURE[1)]

	Electricity[2)] TWh				Oil products[3)] Mill. tons				Coal and coke Mill. tons				Total PJ			
	1977	1978	1985	1990	1977	1978	1985	1990	1977	1978	1985	1990	1977	1978	1985	1990
General consumer sectors[4)]																
- Expected consumption	46.4	48.4	59	70	7.3	7.4	8.2	9.0	1.3[5)]	1.4[5)]	2.0[5)]	2.5[5)]				
--Extra due to uncertainty of model, cold winters etc.			2	1			0.3	0.3								
Power-intensive industry	25.9	27.3	31	34	0.6	0.6	1.3	1.8								
Total gross energy consumption	72.3	75.7	92	105	7.9	8.0	9.8	11.0	1.3	1.4	2.0	2.5	636	655	808	921

1) Figures for 1977 and 1978 are taken from Central Bureau of Statistics' resource accounts for energy.

2) The figures apply to firm power. Allowance is made for a transmission and distribution loss of 16 percent in 1977 and 1978, 15.5 percent in 1985 and 15 percent in 1990 on the net general consumption. This corresponds to 6.4 TWh in 1977, 8.2 TWh in 1985 and 9.3 TWh in 1990. For power-intensive industry the loss is set at 3 percent for all years.

3) Oil consumption connected with refining of crude oil in 1985 is reckoned at 0.3 mill. tons and in 1990 at 0.4 mill. tons.

4) Incl. energy sectors.

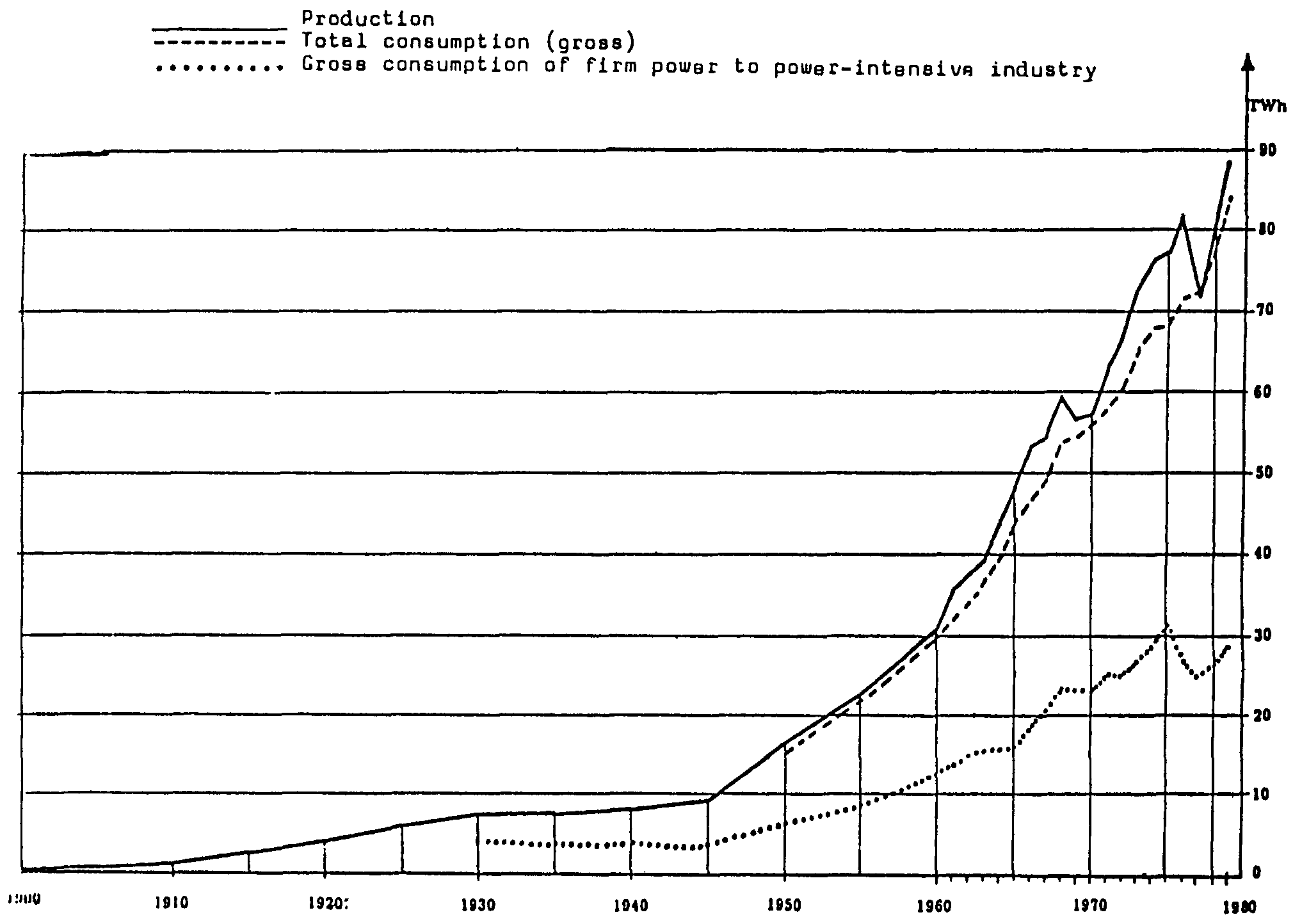
5) Figures apply both to ordinary consumption and power-intensive industry.

TABLE 6. BASIC ALTERNATIVE FOR COVERAGE OF DOMESTIC FIRM POWER CONSUMPTION
(In TWh)

	1977	1980	1985	1990
Definite supplies, incl. import rights of 4 TWh	76	83	91	93
New supplies:				
Improved pooling etc.				1
Large-scale hydropower projects			3	7
Modernization and re-equipping of older hydropower stations			-	1
Small power stations			-	2
Thermal power stations connected with industry			-	1
Own thermal power stations/ Combd. el.+ distr. heating plant/ changes in import rights			-	1
Other energy sources				
(waves, wind, etc.)				-
Firm power production capacity	76	83	94	106

-: less than 0.5

FIGURE 1. ELECTRICITY PRODUCTION AND CONSUMPTION IN NORWAY 1900-1979[1)]



1) For 1978 and 1979. Provisional figures

Sweden

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INTRODUCTION

The long-term objective of Swedish energy policy is for Sweden's energy requirements to be met by lasting, preferably renewable and indigenous, energy sources with a minimum of environmental impact. With this objective in mind, the Swedish energy program aims primarily at reducing dependence on imported oil through energy conservation and through development of alternative sources of energy, both conventional and nonconventional.

There is hardly any oil, gas or coal in Sweden. On the other hand, the country is fairly rich in nonconventional sources of energy. It has been estimated that Sweden's energy requirements theoretically could be completely met in the future through indigenous and renewable sources of energy. However, conventional alternatives to oil, mainly nuclear energy, gas and coal, will have to be used for a considerable period of time. A number of constraints of an economic, environmental and political nature hamper transition to an energy system primarily based on indigenous and renewable sources.

Several studies of the potential of new and renewable energy sources have been made recently in Sweden. Usually they do not differ too much regarding physical and technical factors, but some differences appear regarding assessments of available resources and regarding possible contributions to Sweden's energy supply in 1990.

A thorough assessment of such possible contributions was made in a report from the Energy Research and Development Commission in 1979. In this study, energy sources were divided in three categories:

- Those which can be used immediately with known technology (forest and agricultural residues, peat and refuse).

- Those for which it is possible to estimate the length of their development period and their possible energy contribution (wind, solar heating and upgraded biomass fuels).

- Those for which possibilities can only be estimated after research and development (energy forests, photovoltaics, wave and geothermal energy, etc.).

Table 1 shows the commission's estimates for the year 1990. Table 2 gives the commission's assessment of the technological status for several new sources of energy.

Provided that development efforts are successful, considerably higher contributions can be expected by the year 2000.

The sun already provides more than one-fifth of Sweden's total primary energy in the form of hydroelectricity and forest waste. There is a large future potential for energy forest plantations, because the availability of suitable land on a per capita basis is large. In addition, about 50 percent of Sweden is covered by forests, and other areas of interest include closed down agricultural land or peat bogs.

In the following sections of this paper, each renewable energy source will be discussed in detail with respect to resources, technical and economic feasibility, and environmental and institutional issues.

SOLAR ENERGY

Solar Heating

Roughly 40 percent of the energy consumed in Sweden, or approximately 570 PJ (14 Mtoe), is used for heating, ventilation and hot water production in buildings. About 65 percent of the heat is supplied by individual oil-fired boiler installations. District heating plants supply approximately 25 percent, while electric heating accounts for the remaining 10 percent. Because district heating plants are currently almost entirely dependent on heavy fuel oil, the implication is that dependence on oil in the heating sector is close to 90 percent. To increase the security of energy supply it is essential to reduce dependence on oil. One way of doing this is using solar heat, either directly or indirectly via heat pumps.

Despite Sweden's northern latitude, solar heat is an interesting option. In clear weather, the sun supplies us with energy at a rate of approximately 1 KW per square meter at right angle to the irradiation. Due to changes between summer and winter, between day and night and between clear skies and cloudiness, the annual mean value is reduced to approximately 1 KW per square meter horizontal level. Despite the fact that Sweden's northern position results in an unfavorable distribution of solar radiation between summer and winter, the number of sunshine hours is comparable to that in large parts of central Europe, but less than that in southern Europe, the United States and Japan. About half the annual solar irradiation is supplied during Sweden's nine-month heating season.

Seasonal variations render exploitation of solar heat more difficult unless efficient methods of heat storage can be developed. If solar heat is to be successfully utilized as a means of heating buildings, methods for heat storage from summer to winter will be needed. If solar energy is to be used only to heat tap water, the need for heat storage over longer periods is not critical. With simple, short-time storage approximately half the Swedish annual requirement of hot water can be met by solar energy.

Heat Storage: Development areas of current interest are storage in water, storage in and heat extraction from soil, and chemical storage.

Storage in Water: Heat storage in small water reservoirs is a feature of several solar heating systems ready to be introduced on the market. The heat losses are, however, so large that only short-time storage appears to be feasible. On the other hand, storage of solar heat in very large water reservoirs offers tangible advantages. For one thing, the heat losses will be small in proportion to the total amount of heat stored, and the heating medium permits the use of established district heating technology. These huge storages can be conceived according to different principles. Within the energy research and development program, studies are underway of steel or concrete tanks above ground, pit reservoirs in underground rock caverns, lake and ground water reservoirs.

A number of pilot plants have been built with both concrete tanks and pit reservoirs in underground rock caverns in the size range of 5 to 10,000 cubic meters.

Storage in and Heat Recovery from Soil: This includes not only methods involving active storage in soil, rock caverns and ground water stores, but also heat recovery from passive storages -- soil, rock caverns, lake bottom sediments, and surface and groundwater -- with heat supply from the natural irradiation. Such passive storages constitute heat sources for heat pumps, which then can be used during the coldest period of the year without auxiliary heating.

The most interesting passive storage system consists of shallow ground source heating. This system has reached the marketing stage. Further development and testing nevertheless is required, primarily with regard to applications in differing geological conditions. Results from installations in several Swedish houses indicate that it is possible to produce roughly twice as much heat as the electrical energy used. The technology is becoming economical. However, it has one disadvantage in that relatively large areas of ground have to be used. A normal private home requires a 400 meter tube coil occupying an area of 400 to 500 square meters.

Other passive storage systems are being investigated within the energy research and development program. One subject being studied is the technology of exploiting bottom sediment in lakes and sea inlets. This is an area which already seems interesting from an economic point of view. The possibility of using surface water or flowing groundwater as a source for heat pumps also is being studied.

Among the active storage systems, deep level heating systems have made considerable progress and several experimental building projects have been completed. They are expected to be roughly 30 to 40 percent more expensive than shallow ground source heating systems. Their primary advantage is that they occupy less space, which makes them more suitable for use in densely populated areas.

Chemical Storage: Sweden has made considerable progress in the area of chemical storage. One such system is the chemical hydration heat pump, using the sorption heat of water vapor and certain salts under low pressure. Simple solar heaters thus can be used to charge the storage unit, which then can be sealed and tapped at any time.

Solar Collectors: Industrial production of solar collectors has commenced in several countries, and the number of solar collectors installed has increased very rapidly. Experiences from other countries are, however, of limited value to Sweden, because both operating conditions and applications vary.

Solar collectors have been developed by a large number of Swedish companies and there are several types on the market.

The Swedish climate exerts considerable strains on the solar collectors. Particular attention therefore is devoted to the long-term characteristics. Intensive development work is underway with the aim of reducing problems of corrosion, leakage and thermal expansion.

Some Swedish companies also market complete systems for solar heated tap water. Among the systems installed in Sweden, those for single-family buildings predominate(approximately 2,000). Systems for heating of swimming pools also are being developed.

Within the energy research and development program, development also is carried out on technologies and systems enabling solar heat to be exploited as a supplement to existing heating systems. One example is the connection of solar collectors to the return pipe in a district heating system, enabling the temperature of the return water to be raised. The solar collectors must be able to raise the temperature from between 45°C and 60°C to between 75°C and 80°C, with the culvert system subsequently storing heat. By this means, approximately 10 percent of the fuel in district heating systems can be saved. This type of system is currently under development and work has commenced on construction of a number of pilot plants. A limiting factor is the high cost of solar collectors and the uncertainty of their long-term characteristics.

Heat Pumps: In Sweden, roughly 10,000 heat pump units were installed in 1980. The majority of these have been installed in recent years and consist of electrically powered outdoor air heat pumps for small houses. Larger heat pumps are relatively common in apartments. A few hundred of these consist of large, site-built installations, all of which are used as cooling plants for air conditioning during the summer months.

The difficulties facing Sweden today consist of finding, adapting and combining components in a heat pump system and utilizing heat sources in such a manner that a high annual heat factor and good operational reliability are assured. Distribution technology for low-grade heat also is being developed. In comparison with other types of heating plants, the installation cost for the heat pump is high. The installation cost is roughly three to five times greater than for an oil-fired plant.

Passive Solar Heating: The need for conventional heat supply may be reduced by up to 30 percent by a combination of building technique and installation technique which makes use of the insulation heat and surplus heat from domestic appliances and human beings. As part of the energy research and development program, a number of low-energy houses have been built and are now being evaluated.

Development Situation: Solar heating technology thus embraces several different methods for heating buildings and water, which are currently at different stages of development. The situation is characterized by rapid progress in which many ideas and system solutions are being evaluated in different applications, such as in private houses and multi-family dwellings, in new buildings and existing buildings.

The objective of the energy research and development program is to have tested and evaluated various solutions by 1985 to an extent sufficient to establish a basis for governmental decisions concerning the role and introduction of solar heating in Sweden.

Costs: In assessing the economy of solar heating systems, allowance must be made for the uncertainties concerning the lifetime of installations and anticipated cost reductions resulting from production in long series and increases in scale.

For medium-sized solar heating centrals servicing a few hundred apartments or homes and designed to give the lowest cost, the heating cost is currently estimated at $80 to $120 per barrel of oil equivalent.

The cost of solar heated tap water for the systems already installed is $120 to $160 per barrel of oil equivalent, but it is expected that this figure could be reduced by at least one-third. For solar heating installations connected directly to the district heating network, the costs are estimated at $60 to $80 per barrel of oil equivalent.

Energy Contributions: The uncertainties about the development of different solar heating technologies render quantifications of possible energy contributions difficult. If it is assumed that commercialization can be achieved in the mid-1980s, it is estimated that 10 PJ (.2 Mtoe) can be produced with solar energy by 1990, primarily in district heating systems and for heating tap water. By the year 2000, the production may be at the rate of 35 PJ (.8 Mtoe) per annum, a large proportion of which will relate to systems with year-round storage.

Solar Power

This relates to solar energy which is converted directly into electrical energy or fuel (such as hydrogen). Solar power technology may be divided into three sub-areas: thermal solar power stations, semi-conductor cells and photochemical systems.

Thermal Solar Power: Sweden is participating in an International Energy Agency (IEA) cooperation project comprising a central receiver tower and solar farm plant built in Almeria, Spain.

In the semi-conductor field, international development work on solar cells is highly dynamic. Swedish research contributions are concerned primarily with performance control, evaluation and testing of solar cells. A trial plant with a peak power of 1 KW has been installed for the purpose of testing silicon solar cells under Swedish climatic conditions.

The photochemical systems consist partly of electrode/electrolytic systems which provide electric energy, and partly of chemical conversions to substances richer in energy. A research group concerned with photochemistry is being financed in Sweden. The work consists primarily of monitoring international developments, studying electronic transmission and relevant chemical reactions, and developing photochemical solar cells.

It is not envisaged that these methods will be able to make any substantial contribution to Sweden's energy supply by 1990. By the year 2000, the solar cells may, in the most favorable circumstances, account for a few tenths of a terrawatt-hour. The other methods are not expected to be able to give any contribution. In the long-term perspective, the photochemical processes may acquire some importance.

HYDROELECTRIC POWER

Sweden has an ample supply of hydraulic (hydro) energy, particularly in the northern parts of the country. Hydroelectric power was developed at an early stage and has been a basis for the industrialization of Sweden. A nationwide transmission and distribution network has been built up, and electricity is widely used in industry and all other areas of society. Sweden thus has a century-long experience of hydro power, and Swedish companies are active around the world in consulting, construction and equipment for hydro power projects and electricity transmission. As matters stand today, hydroelectric power has been exploited for an annual production of more than 215 PJ (60 TWh). A technical potential exists for an increase of annual production to 470 PJ (130 TWh), of which 340 PJ (95 TWh) is economical at current energy prices. However, to preserve wildlife and the natural environment, Parliament has decided to impose restrictions on the further expansion of hydro power. It is expected that hydroelectricity production in 1990 will be about 240 PJ (65 TWh). The government has promoted the development of mini-hydro power plants in the range of 100 KW to 1,500 KW through special economic incentives.

PEAT

Ten percent, or 54,000 Mm^2, of Sweden's total area consists of marshland. This marshland varies in age from a few thousand up to 10,000 years. The annual rate of growth is .1 to .5 mm, the implication being that in practical terms peat is a nonrenewable resource. The thermal value of the peat resources is estimated to be equivalent to some 3,000 million tons of oil. Swedish peat resources currently are being surveyed as a basis for a more precise estimate with regard to amount and quality.

Peat has been used as fuel for a long time in Sweden and elsewhere. The Swedish peat industry expanded rapidly during World War II and at most, in 1945, produced 1.5 million tons. Currently, only 300,000 tons per annum is produced, all of which is used for soil conditioning. Several Swedish companies are engaged in the production of soil-improvement peat and are thus familiar with the technology of conventional peat extracting methods.

Most of the peat produced is either milled or sod peat. Production is highly dependent on climatic and seasonal conditions. Dewatering problems constitute a major constraint, and certain projects within the research and development program deal with improvement of the currently used dewatering technique. Methods for carbonizing in wet vessels are under investigation.

Transportation of peat is relatively expensive and consequently only large consumers have an economic interest in the use of peat at the present state of the art. However the techniques relating to peat supply to small and medium-sized consumers are constantly improving, and full-scale trials are planned. Efforts also are being made to improve peat combustion, particularly in medium-sized furnaces (.1 to 1 MW).

The peatlands, which comprise part of the wet areas, are a sensitive area of fundamental importance to the ecological balance in their surroundings. Bearing this in mind, peat exploitation should not be started without a careful consideration of the various consequences involved. Environmental aspects may restrict peat production in certain sensitive areas protected for nature conservancy reasons, but are unlikely to severely limit or restrict peat utilization envisaged in present plants.

In Sweden, energy from peat is currently at an introduction stage. Several new extraction and combustion projects have been started during the past few years. By 1990, it is estimated that the amount of peat being used could be equivalent to 20 to 50 PJ (.5 to 1 Mtoe). As a result of certain measures, among them the thorough surveys conducted in the 1980s, the expansion of peat exploitation could be more rapid.

Peat production costs are estimated at between $9 and $17 per barrel of oil equivalent, excluding the costs of transportation which, like the production costs, depend on local conditions. Within reasonable transport distances, peat as a fuel now can compete with both coal and oil.

BIOMASS

Wood Waste

The total area of forest land in Sweden is 23.5 million hectares, including a small portion of abandoned agricultural land. The annual growth of trunk wood with bark is 75 million cubic meters per year (544 PJ or 13 Mtoe). The total growth is estimated at 120 million cubic meters. In a corresponding manner, Sweden's timber store may be estimated at 3,800 million cubic meters of biomass (27,600 PJ or 660 Mtoe).

In the Swedish forestry sector, 75 million cubic meters of timber and pulpwood per annum is harvested for use by the forest products industry. Byproducts are used by the industry to a very great extent as fuel.

Approximately 45 million cubic meters in the form of roots, felling residues, clearing and thinning timber and deciduous trees are left on the felling sites. The energy content of these residues amounts to approximately 325 PJ (7.8 Mtoe).

Present-day forestry uses the so-called assortment method, according to which limbing and sawing of the logs into standardized lengths and quality classes takes place on the felling site. Organized utilization of forest energy is taking place experimentally. Individual forest owners and private individuals collect residual wood from felled areas for use as fuel. Similarly, minor quantities of smallwood trees in clearings and wood left behind after logging merchantable timber are collected. At the end of 1979, annual consumption of wood and chips used as fuel was estimated at 4 million cubic meters solid measure under bark (30 PJ or .7 Mtoe). The rate of increase in small-scale use of wood and chips is high.

A few attempts have been made on a large scale to perform thinning operations with removal of unlimbed parts of trees, which are transported to the mills for limbing and barking and then used as fuel. Machinery and vehicles of suitable types are, however, not available for large-scale utilization. This applies in the first instance to removal of the stump wood, but also to other residues.

It is believed that for ecological, techno-economic and social reasons only a part of the physically available volume of forest residues, 45 million cubic meters, can be collected. The exploitation of forest energy is expected to develop as shown in Figure 1.

The total yield with present-day felling methods is expected to stagnate at 17 million cubic meters, equivalent to 120 PJ (2.9 Mtoe). With the current level of oil prices, utilization of this source of energy in Sweden is economical in many instances but it temporarily may be constrained by technical and infra-structural factors.

Future logging methods, such as the whole tree and part tree methods, would enable a greater proportion of the tree residues to be extracted for energy purposes (26 million cubic meters/solid measure under bark per annum, equivalent to 190 PJ or 4.5 Mtoe). As part of the energy research and development program, considerable efforts are being devoted to improved felling techniques. These effects aim at development and full-scale testing of a first generation new technology by 1987.

Forest energy based on forest residues is primarily expected to be used in hot water centers, district heating plants, industrial boilers and on farms to substitute for oil and coal. If this is to be achieved to any considerable extent, it is necessary that firewood becomes established as a commercial commodity and that reliable distribution channels are set up. A number of industrial boilers, hot water centers and heating plants for chips and wood-firing have, however, already been built, partly with government financing. Plans have been made for a number of additional plants.

New and improved techniques for conversion to fuels that are easy to handle and transport need to be developed.

The environmental restrictions for forestry energy production are considered negligible except at a local level for certain lean soils. There is some uncertainty about the very long-term effects of large harvests of forest energy.

The production costs of wood waste depend on local circumstances and on the production technique applied. With present-day techniques, the production costs are usually in the range of $11 to $23 per barrel of oil equivalent.

Preparation and conversion costs must be added to get figures comparable to oil prices.

An important overall consideration that has to be borne in mind when assessing the potential of forest energy in Sweden is the conflict between using the forest for energy purposes or as a raw material in the forest industry.

Energy Forestry

Energy forests are areas cultivated with species of trees that are specially selected because of their rapid, high-energy fiber growth rate. The species concerned are deciduous trees such as Salix and Populus. Energy forest cultivation implies establishment on specially selected areas, where growth conditions (soil type, water, stock of nutrients and inclination) are favorable, or large coherent areas of densely cultivated deciduous forest. They require a growth period after planting of one to three years before they can be harvested for the first time. In a steady-state stand, harvesting cycles of one to three years are likely. Each cultivation is expected to have a growth-favoring life duration of 20 to 30 years, after which new plants will have to be planted.

An important problem is to develop species that can be cultivated in such a manner as to make energy forestry competitive. Comprehensive work currently is underway aimed at evaluation and selection of parent trees for the production of cuttings. Small-scale experimentation hitherto indicates a production of 20 tons dry substance -- 60 cubic meters per year per hectare, which is considerably in excess of even the highest previously observed production volumes in forestry in cold climate areas.

As part of the energy research and development program, large-scale experimental cultivations have been commenced both on abandoned agricultural soil and on marshland. The goal is to enable the production potential and costs of energy forests to be reliably appraised by the mid-1980s through advancement of knowledge, technical development and large-scale trials with complete supply systems.

Because energy forest cultivation is a new field of activity in Sweden and throughout the world, it is also necessary to develop suitable machinery. Energy forests will be harvested mechanically with newly developed, highly efficient machine systems. The kind of machinery will vary with the sizes of the cultivation units, but also other factors such as the bearing strength of the soil will be of importance. Machine systems for cultivation and harvesting of energy forest in small, medium-sized and large plantations are currently being designed and prototypes are manufactured under the auspices of the energy research and development program.

Prior to use, the harvested fiber mass has to be fractionated, prepared (dried), stored and transported.

The ecological and environmental problems related to energy forest cultivation -- such as influence on groundwater, nitrite leakage, insect combating, protection of plantations against voles and elks -- are being investigated as part of the energy research and development program. Environmental restrictions may prove to be an obstacle to intensive cultivation on peat land.

Energy forest cultivation is at an early stage of development and may not be expected to make any major contribution to the energy supply before the turn of the century. A cautious appraisal is that approximately 3 million tons of dry substance, or 50 PJ (1.2 Mtoe), may be produced by the year 2000. Estimates of the production costs vary between $7 and $36 per barrel.

Energy from Agriculture

Straw: In Sweden, straw cereals are cultivated on approximately 1.5 million hectares. The production of straw is approximately 4 tons per hectare, a total of 6 million tons per year. A significant proportion of this volume is plowed back into or burnt on the fields. It is assumed that between one-third and one-half the annual production of straw could be harvested for combustion, implying an energy contribution of approximately 40 PJ (1 Mtoe). Straw has long been marketed on a commercial basis and straw-fired boilers are on the market.

The major problem relating to exploitation of straw as a source of energy is that the entire quantity is obtained during a brief harvest period at a time when agricultural labor is fully occupied. The straw also has to be stored to cover the fuel requirement during a greater part of the year.

There are no appreciable environmental restrictions to straw production. The production costs lie in the range of $14 to $22 per barrel of oil equivalent.

Biogas: Farmyard manure can be fermented to produce methane gas. The total potential of farmyard manure is estimated at approximately 54 PJ (1.3 Mtoe). At present, there are several pilot plants in operation in Sweden. One of the reasons this technique is expected to be used only to cover the energy requirements of a small number of larger farms is the difficulty encountered in distributing the gas.

In recent years there also has been an increasing interest in using waste products from the sugar industry for energy production.

Energy Crops: This is the term applied to annual plants grown on agricultural soil for the sole purpose of energy production. Among crops being studied in this context are grass, potatoes, sugar beets, fodder sugar beets and hemp.

To become competitive, the energy crops must give a significantly greater harvest and/or be produced and harvested at lower cost than grain and straw. As a result of agricultural plant improvement, the yield of agricultural crops is increasing steadily at the rate of approximately 50 kilograms of dry substance per hectare per year.

With the Swedish climate and current carbon dioxide contents of the atmosphere, it is believed that the limit is about 25 tons of dry substance per hectare per year compared to the current 5 to 10 tons. It is estimated that approximately 700,000 hectares could be used for production other than foodstuffs by 1990.

The energy research and development program also embraces research concerning crop selection and crop rotation, soil characteristics, production yields, environmental consequences, economic aspects and conditions in connection with introduction as well as a large field cultivation trial. No serious environmental limitations are foreseen. Ecological research relating to crop rotation, fertilization and the use of biocides is nevertheless necessary. Through research, including large-scale cultivation trials, the goal is to enable a reasonably reliable appraisal of the potential of different energy crops in competition with other uses.

Aquatic Biomasses: On Swedish latitudes, it is probable that among aquatic biomasses, only reeds and algae will be able to make an appreciable contribution to the energy supply. Natural stands of reeds are estimated to cover an area of approximately 100,000 hectares, which, with a yield of approximately 5 tons of dry substance per hectare, gives 9 PJ (.2 Mtoe) per year. Small-scale reed cultivation experiments have indicated that the cultivation potential is ten-fold and harvesting machines have been developed. An important feature of reed cultivation is that harvesting is performed during the winter when the need for fuel is at its greatest and the workload on agriculture is at a low level.

Tests with algae cultivation have given interesting results, and trials on a larger scale are being planned.

WIND

Since 1975, Sweden has conducted an extensive research and development program on wind energy. The objective is to establish, not later than 1985, a basis for decisions relating to a large-scale introduction of wind power in Sweden.

A predominant part of the wind energy program is concentrated on building large land-based plants connected to the electric power grid. An evaluation and testing program has been conducted since 1977 at a small pilot plant of 60 KW.

Two full-scale prototypes have been procured from Swedish companies and construction work will be completed by the spring of 1982. They are twin-bladed, horizontal axis power stations with a tower height of approximately 80 meters, a turbine-blade diameter of 78 meters and a rated output of 2.5 and 3 MW, respectively. They differ from each other in the materials chosen for the tower, turbine blades and hub.

Detailed knowledge about wind conditions is an essential basis for any significant wind power program. A large-scale measuring program was initiated in 1979. The wind velocity will be simultaneously measured once every hour from high towers at several places in Sweden.

Current appraisals indicate that the environmental effects of wind power will be small, although the picture is not yet completely clear.

The costs of wind power have been estimated at 3 to 7 cents per kilowatt-hour, excluding costs for power reserves. There is considerable uncertainty in estimating power station costs, wind conditions and annual production. The potential for wind power is estimated at approximately 110 PJ (30 TWh) in Swedish land areas with wind velocities in excess of 7 meters per second. The potential in marine areas is believed to be roughly the same. If the research and development program gives favorable results, it is anticipated that an expansion equivalent to as much as 55 PJ (15 TWh) will be possible during the 1990s.

OCEAN ENERGY

Internationally, wave energy technology is at a very early stage of development. Sweden is engaged in limited development and experimental work relating to small buoys for Swedish fairways with conversion to electric energy through a linear generator. A small plant is being tested.

The wave energy reaching the Swedish coast is very modest in an international comparison, approximately 4 KW per meter of wave front during the ice-free period.

Utilization of wave energy is surrounded by many uncertainties. The plants will have to be constructed to resist storms, ordinary wear, corrosion and icing. The potential for Sweden has been estimated at approximately 10 to 55 PJ (3 to 15 Twh) per year at a cost of 6 cents per kilowatt-hour.

Conceptual design work has been carried out on salt and thermal gradient energy, but neither seems to be feasible in Sweden's cold and brackish waters.

Swedish industry participates in the international ocean thermal energy conversion development. The Swedish contribution is mainly concentrated on advanced heat exchanges and turbines.

GEOTHERMAL ENERGY

In the south of Sweden, deep layers of sandstone containing hot water can be found in the sedimentary bedrock. The heat content amounts to approximately 7,200 PJ (170 Mtoe) for temperatures above 50°C and approximately 14,400 PJ (340 Mtoe) above 30°C. This hot water is relatively easy to reach through drill holes and the technology, which is largely known, is becoming profitable with present oil prices. Attention must be devoted to corrosion problems in view of the high salt content of this water.

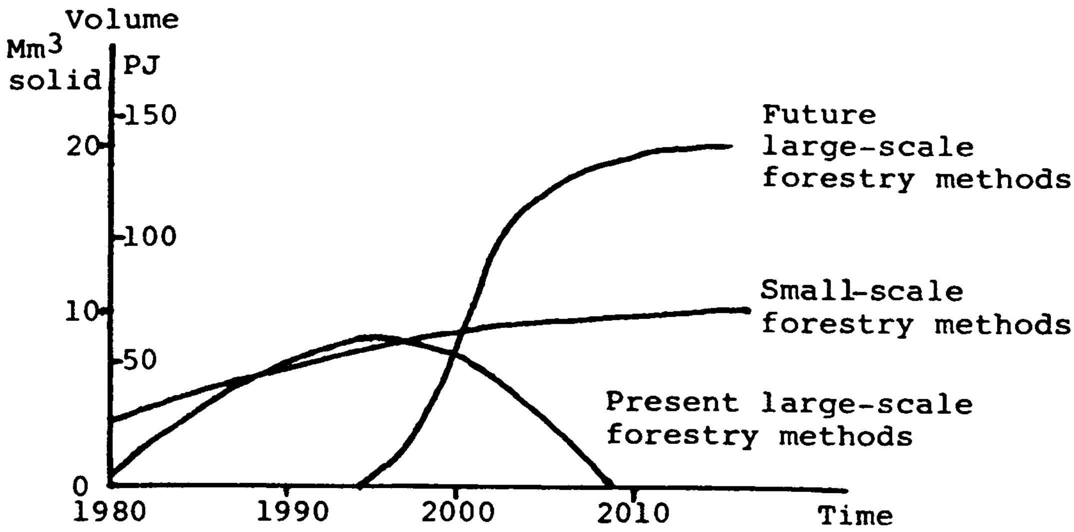
TABLE 1. ESTIMATED RENEWABLE ENERGY CONTRIBUTIONS BY 1990

Wind energy	3,5 - 7 PJ	(1 - 2 TWh)
Solar heating	10 PJ	(0,25 Mtoe)
Forest energy	80 - 125 PJ	(2 - 3 Mtoe)
Peat	20 - 40 PJ	(0,5 - 1 Mtoe)
Agricultural waste	8 - 20 PJ	(0,2 - 0,5 Mtoe)

TABLE 2. DEVELOPMENT STATUS

	1980-1985	1985-1990	After 1990
Wood waste Peat Straw	Introduction in small and medium-sized plants	Might gradually develop into commercialized fuels	
Solar heating with seasonal storage	Increasing R & D activities	Empirical data from full scale trials	Might develop to commercialized technique
Wind energy	Empirical data from prototypes	Empirical data from demonstration groups	Might develop to commercialized technique
Energy forest plantations	R & D activities	Empirical data from full scale trials	Might develop to commercialized technique
Wave energy	R & D activities		
Geothermal energy	Survey of geological prerequisites		
Solar cells	R & D activities		

FIGURE 1. EXPECTED FOREST ENERGY DEVELOPMENT



United States

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INTRODUCTION

Currently, renewable energy sources meet more than 5 percent of U.S. energy needs. Most of this fraction -- more than 3 percent of U.S. energy consumption -- is supplied by hydro power. The second major renewable resource in present use is wood, which now provides about 2 percent of the national energy supply. Wood's increasing share of the energy budget reflects Americans' growing reliance on wood-burning heaters in homes, and industry's use of wood residues in the boilers of pulp and paper factories and other wood-related operations.

The technical feasibility of a number of new technologies has been proven, but most of the systems based on these technologies have not yet become sufficiently competitive in the United States to warrant widespread use. For example, photovoltaic cells -- which convert sunlight directly to electricity -- provide critical energy for satellites in the U.S. space program, but they remain too expensive for most common electricity uses. As the price of power from the various new and renewable energy systems can be reduced through research and industrial development, these systems can be expected to play growing roles in satisfying U.S. energy needs.

A National Commitment

Until recently, research activities in the U.S. on new and renewable energy sources were small. In 1970, the federal government funded only a few hundred thousand dollars annually for research in these areas. One decade later, annual federal outlays supporting research were in the hundreds of millions of dollars. Moreover, thousands of companies, citizens' groups, and individuals are experimenting with, installing, buying, servicing, and selling energy systems based upon new and renewable energy resources.

In the mid-1970s, public and governmental interest in new and renewable sources of energy was accelerated by the rapid rise in oil prices and by supply problems. The overall U.S. energy program has been based on both executive and legislative inputs. In terms of executive agencies, the U.S. Department of Energy has the lead responsibility in research on new and renewable energy sources.

The Domestic Policy Review of Solar Energy (the DPR for short), was formed in 1978 to evaluate the potential for the accelerated use of solar-based energy sources. The final report of this group concluded that "significant potential exists for expanding the nation's use of solar energy" and that "many solar technologies are already economic and can be used in a wide range of applications." With concerted efforts to overcome the many barriers to implementing renewable technologies, the report further states, the United States could cost-effectively obtain as much as 20 percent of its energy supply from renewable sources by the year 2000.

Although progress in the use of renewable energy will be influenced by unpredictable factors, it is possible in general terms to outline a role for renewables. The relative contribution of hydro power to electricity supplies is expected to increase moderately over the next two decades because the best and largest U.S. resources already have been developed. During this period, biomass-based power systems are expected to overtake hydro power as the major renewable energy source. The principal contributions are expected to be the direct combustion of organic matter to produce heat, and the conversion of biomass into alcohol fuel, methane gas, and hydrocarbon-based chemical feedstocks. Biomass-based energy also will be used by electric utilities and residences.

Solar thermal technologies -- both the low-temperature systems most commonly used to heat water or buildings and the intermediate- and high-temperature systems used to provide steam for industrial use or electricity generation -- are expected to provide small but growing shares of energy for the residential, industrial, and utility sectors by the year 2000. By that time, wind power, photovoltaic cells, and ocean thermal systems also are expected to contribute notably to utility electrical output, and a portion of the electricity production from each will come from small, independent systems.

In 1980, following the second major round of global oil price rises, the U.S. Congress established targets for the production of synthetic fuels, among them oil from shale and tar sands as well as liquid fuels and gas from coal and biomass. By the early 1990s, the United States hopes to be producing at least 2 million barrels a day of synthetic fuels, with oil shale and tar sands accounting for perhaps half that amount. (Two million barrels a day is equivalent to more than four "quads" per year of energy. One quad is 10^{15} Btu and almost the same as 1 exajoule or 10^{18} joules.)

Private and Governmental Roles

The United States relies mainly on private industry for the development of technologies and for the production and delivery of energy, although industry is sometimes aided by the government when the normal workings of the marketplace do not adequately serve national security, social, economic, or environmental objectives. In the case of new and renewable energy, both the public and the federal government have come to recognize the compelling national interest in hastening the commercial availability of alternative energy sources. Impediments to the employment of new and renewable energy have been identified, and ways are being sought to help overcome them. The major barriers are: high initial cost; limited public awareness of and information about economically competitive technologies; early stages of technology development; and counterproductive federal, state, and local government regulations and utility policies. Domestic price controls and tax incentives to stimulate oil and gas production also have been a major factor in keeping new and renewable energy sources from competing effectively in the marketplace, although this problem is less severe now than in the past.

To overcome these barriers, the U.S. government uses four principal tools: research and development, financial incentives, regulatory functions and information dissemination. Commercialization of new technologies is properly the role of private industry. Federally funded research and development is concentrated on long-term, high-risk, and potentially high-benefit efforts. Presently the federal government is decreasing the regulatory controls it has over the economy -- it has ended price controls on oil and is considering doing the same for natural gas.

Short-term financial incentives, especially tax credits, have increased in recent years and have greatly accelerated the commercialization of new and renewable energy technologies. These financial inducements indicate that new and renewable technologies are considered ready for practical use.

Perhaps the most significant financial incentive is the federal income tax credit of 40 percent (up to a total credit of $4,000) for individual homeowners who install renewable energy devices. For example, a homeowner who spends $2,000 on a solar hot water heater will pay $800 less in federal income taxes that year. Other important financial incentives include grants for experiments and demonstrations, loan subsidies for energy improvements in housing and loan guarantees for companies investing in geothermal energy, ocean thermal energy and synfuels systems.

Several federal agencies are involved in accelerating the adoption of new and renewable energy. The major agency supporting research, development, demonstration, and information dissemination is the Department of Energy. A portion of its research funding goes to the Solar Energy Research Institute and to various national laboratories. (Most federally sponsored energy research is actually carried out by private firms and universities under contract.) The Department of Housing and Urban Development is involved in promoting the use of renewable energy systems and conservation in housing. To mitigate potential environmental problems by integrating environmental planning into all energy resource development, the Environmental Protection Agency has a program assessing the impacts of all energy systems. The National Aeronautics and Space Administration supports the Department of Energy in research and development of many technologies (especially wind and photovoltaics). The Department of Agriculture has a major responsibility for research and development concerned with biomass-based energy, especially alcohol fuels, and for solar energy systems for farm and rural uses. The Department of Commerce encourages the establishment of renewable energy industries. Besides these federal departments, a quasi-governmental Synthetic Fuels Corporation has been established by Congress to provide loan guarantees and other subsidies for synfuels (including oil from shale and tar sands and liquid fuels from biomass). Many other federal agencies are directly and indirectly contributing to the national effort to develop new and renewable energy technologies.

The Department of Energy actively participates in international cooperative research, development and demonstration programs. It has bilateral cooperative agreements in new and renewable energy technologies with a number of countries and is involved in many multilateral cooperative programs (most under the umbrella of an International Energy Agency -- IEA -- agreement). In addition, federal laboratories are providing technical support to the Agency for International Development (AID) for various projects in developing countries.

Complementing federally sponsored efforts are state and local government activities aimed at promoting the use of renewable energy at the community level.

About half of the 50 states provide homeowners and renters with some additional financial incentives for the purchase of solar water or space-heating systems. These incentives, together with the federal tax credit, offer a strong inducement to potential buyers. Some cities also provide special incentives for the installation of solar devices in economically depressed inner-city zones.

Many of the states have implemented strong incentives for the use of renewable energy systems. In 1977, California established a state tax credit of 55 percent for solar investments (less for those who also claim the federal tax credit). California now accounts for nearly half the country's sales of solar hot water heaters. Arizona recently implemented a state tax credit of 35 percent, which can be added to the federal tax credit. Many states have enacted laws to provide special incentives, such as exemptions from real estate or sales taxes, and to protect landowners' access to sunlight. The latter law prohibits obstructions that would block sunlight from reaching existing solar systems.

Most industry efforts to develop new and renewable energy technologies have been independent of government funding. At present, industry's financial commitment to research and development on new and renewable energy technologies is comparable to the federal government's. Nevertheless, indirect governmental support -- such as tax credits, loans and market development activities -- has helped hundreds of companies begin manufacturing and distributing solar heating systems, wood-burning stoves, wind generators and other small-scale renewable energy technologies. Thousands of other companies are involved in the sale, construction and maintenance of new and renewable energy systems. Annual sales of solar collectors now amount to several hundred million dollars. Industries that use and refine biomass (including wood and gasohol) provide energy worth several billion dollars annually. Construction of hydro power (especially small or mini-hydro) facilities is increasing rapidly. U.S. sales of photovoltaic modules and systems are now more than $50 million annually.

In the United States, industry's and government's solar development programs are complemented by the activities of many individuals, community groups, and non-profit organizations. As one indication, the U.S. Section of the International Solar Energy Society boasted more than 5,500 members in 1980, compared to a few hundred in 1970. The Solar Lobby, a citizens' organization that works to marshall support for renewable energy, has about 35,000 dues-paying members. These and other private groups help disseminate information about renewable energy and familiarize people with solar technologies.

SOLAR COLLECTORS: LOW TEMPERATURE

The three keys to the efficient collection of low-temperature solar energy are the judicious use of transparent glass or plastic, the reduction of heat loss and the movement of captured energy so it can be used or stored.

In the United States, low-temperature active and passive solar systems for heating space and water can meet most building energy requirements. Although the total number of solar facilities is still less than 1 percent of all potential users, the basic requirements for a successful commercial industry are in place: a well developed industry infrastructure and a market in which the new products can compete successfully.

In agriculture, requirements for low-temperature heat are substantial, especially for crop drying. Yet, only a few hundred solar crop dryers are now in use because the need is not year-round and do-it-yourself systems require farmers to invest considerable time building and installing them.

In industry, where low-temperature heat is needed year-round, low-temperature solar applications have seen some modest commercial growth. A promising approach is the solar pond, which may become a major future supplier of solar industrial energy, perhaps ultimately for generating electricity using low-boiling-point fluids (such as freon) to drive turbines.

Low-temperature solar technologies can also be used for cooling. Because the need for cooling peaks when insolation is greatest, and because using a collector to both cool and heat is often more cost-effective than a single purpose unit, solar-powered cooling has considerable attraction. The present drawback is high cost; fewer than 100 systems that are not federal demonstrations operate in the United States.

Economics

Low-temperature solar thermal systems are a market-ready technology. Least expensive are the simple design changes an architect can make in the placement of windows and overhangs in new buildings. Indeed, these changes can be money savers from the start, if they enable a building owner to install a smaller heating plant than otherwise would have been needed. Skylights, greenhouses, sunspaces and other passive design features are beginning to earn a wide following on both aesthetic and financial grounds; repaying the costs of these features through fuel savings can be accomplished in only a few years.

Also cost-effective in some cases are simple bag-like air collectors for crop drying. Some farmers can recoup their investments in as little as a year or two.

Water heaters may have a pay-back period as short as four years in special circumstances. Although costs of installed solar water-heating systems generally are above $300 per square meter, the cost is justified when the alternative is electricity, especially in view of the 40 percent federal income tax credit and additional tax advantages available in many states. Active space-heating systems tend to be somewhat cheaper than water heaters on a per-square-meter basis, but they must be larger. On the other hand, paying back the initial investment on these systems may take longer than for water heaters because they are most needed in winter when the incidence of sunlight is lower.

Solar ponds may turn out to be the cheapest of all low-temperature solar collectors (although this finding is largely hypothetical because few have been constructed). Ongoing studies and experiments have projected that a cost of $4 per gigajoule appears within reach. (A gigajoule is very nearly 1 million British thermal units -- MBtu. Oil at $36 per barrel is approximately $6 per gigajoule.)

The economics of solar cooling depends strongly on the possibility of using the collectors year-round to provide heating as well. At present, these systems are still significantly more expensive than conventional ones.

Costs for all solar systems are expected to decline as experience is gained. By some estimates, energy from renewable sources will average $12 per delivered gigajoule by 1985 and $9 per gigajoule by 1990 -- less even than natural gas might cost by 1990.

Private Activities

More than 200 U.S. companies are manufacturing low-temperature active solar systems for heating space and water. Of these, the 10 largest have approximately three-quarters of the business. An estimated 7,000 companies are involved in installing low-temperature active systems. Many of these companies are heating or plumbing businesses that have added a solar line.

Collector sales records show phenomenal market growth. Approximately 2 million square meters of collectors were sold during 1980, totaling about $150 million. Of this total, about 30 percent were domestic hot water applications and 70 percent were lower-temperature systems. These sales represent a growth of 23 percent since 1979, and annual sales growth has averaged more than 40 percent over the past five years.

Passive system use is harder to gauge than active system use. Many architects have enthusiastically embraced passive solar design, but their influence has not yet been felt everywhere. Still, many new companies are now manufacturing and selling greenhouses. Overall, the passive solar industry now receives little direct federal support, and research conducted within the industry is aimed at product improvement -- especially at making the systems more dependable, durable and controllable.

Key to the near-term future of solar technologies, particularly solar water-heating systems, is the promotional role utilities play. Some utilities give low-interest or no-interest loans or support other innovative financing schemes to enable their customers to buy solar systems. About 20 utilities (among them, the nation's largest) have such financing programs today. Most utilities are reserving judgment on financing, but nearly all are at least investigating low-temperature solar systems, both on their own and through industry organizations.

Widespread support for low-temperature solar design also has come from private citizens organized into community groups. In most states, solar energy associations have taken on the task of educating the public and government officials. Collectively, by sponsoring informational meetings and preparing material tailored to local conditions and needs, these groups are playing a catalytic role in getting solar technologies into wider use.

Government Activities

Federal activity in the development and commercialization of low-temperature solar thermal technologies has been extensive and diverse. Since the mid-1970s, when residential systems were considered ready for commercialization, government has supported the construction of more than 14,000 residential demonstration units. This demonstration program is nearing completion, and federal support has shifted to the 40 percent solar tax credit (up to a maximum $10,000 investment).

Federal efforts to reduce consumer costs have been augmented by research and development activities (funded at a level of approximately $20 million annually) on active and passive solar thermal systems. Because of the near-term commercial readiness of active and passive solar systems, the need for information dissemination and for training programs has been considered to be more important with these technologies than with most other renewable energy options.

Support for low-temperature agricultural and industrial applications -- greenhouses, crop dryers, solar ponds and the like -- has paralleled that for the residential and commercial solar programs. All have been the focus of comparable research, development and demonstrations. Corporate purchasers of any of these technologies are eligible to receive a 15 percent federal investment tax credit on top of the 10 percent credit available for any industrial capital expenditure.

State and local governments have been more supportive of low-temperature solar technologies than of any other renewable energy equipment. Following California's lead, most states allow buyers of these systems relief from various taxes on income, property and sales. Colorado has a 30 percent tax credit (which unlike California's 55 percent credit can be added to the 40 percent federal income tax credit), so Colorado residents receive a 70 percent discount on their solar systems. Some cities, particularly in California, have set up municipal solar utilities to finance these systems for private citizens.

Projections

If 20 percent of U.S. energy were to be derived from renewable energy sources by the year 2000, it could mean getting about 4 exajoules from low-temperature solar thermal systems. (The exajoule is very nearly equal to a "quad" -- 10^{15} Btu. The total U.S. energy use is now about 80 exajoules.) Early estimates indicate that this amount of energy will be allocated in the approximate ratio of 2:1:1 among the active, passive and low-temperature industrial applications. Obtaining 2 exajoules per year from active solar heating technologies will require installing solar technologies in 30 million to 40 million existing homes, and in more than half of all new homes.

Displacing this much energy will, of course, entail meeting certain cost projections too. If projections for the active solar hot water contribution are to be met, a drop from today's prices ($9 to $12 per gigajoule) of about one-third will be needed. A smaller cost reduction is foreseen for the active and passive solar heating equipment, which presently costs about $12 to $16 per delivered gigajoule. If prices for gas, oil and electricity rise, many solar systems should become cost-competitive by 1985-1990.

SOLAR COLLECTORS: INTERMEDIATE AND HIGH TEMPERATURE

Solar systems that concentrate sunlight can achieve temperatures exceeding 1,000°C. At least five different techniques for concentrating solar energy are being developed. One is to align a series of flat mirrors at the proper angle to reflect the sun's rays to a fixed receiver. These mirrors track the sun to keep sunlight focused on the receiver. This system is called the "power tower" because the receiver is usually supported on a tower. It is expected to be the lowest cost solar thermal means for producing large amounts of power.

A second technique involves tracking the sun with a "parabolic dish." Looking and functioning much like large radar antennas, the dishes can achieve temperatures exceeding 1,000°C on an absorber surface at the dish focus. If a heat engine is placed at the focal point, converting heat to electricity can be highly efficient. Alternatively, a heat-activating chemical reaction can transfer energy away from the focal point. The parabolic dishes are excellent for dispersed applications of process heat and electricity. Community electric systems of less than 10 megawatts appear to be an attractive market for parabolic dishes in the 1990s.

A third technique entails the use of linear "parabolic trough" mirrors curved in only one dimension. With the focus as a line rather than a point, parabolic trough systems can produce heat at temperatures up to 300°C and are cost-effective for many applications.

The fourth technique relies on the use of fixed "hemispherical bowls" with movable receivers. Although the concentrated energy obtained with the bowls, which are sunk in the ground, is not as intense as that obtained with a parabolic dish or the power tower, having the mirror fixed in place affords mechanical advantages. A linear system with fixed facets and a movable receiver also is being developed.

Another technique to concentrate solar radiation is with magnifying lenses. Because a solid lens would have to be extraordinarily heavy to be big enough to produce power in large quantities, a modified lens is being developed. Molded in plastic, this stepped "Fresnel" lens is no thicker than a pane of glass, but it concentrates as though it were many times thicker. Like mirror concentrators, it can focus to either a point or a line and must track the sun continuously.

In the first four techniques, the reflector used is most often a silver-plated, weather-protected glass mirror. Alternatives being developed include those made of polished aluminum, plastic films and glass "sandwiches." The support structures are made of plastics, wood, metal, concrete or foam glass, while the focal-position receivers are made of glass, ceramic or metal. Oil, water/steam, air, liquid metal or liquid nitrate salt carries the heat away from the receiver.

Either the receiver or reflector (or lens) surface must track the sun at approximately the 15° per hour rate at which the earth rotates. Accurate tracking requires sun sensors, motors and a logic or clock system to compensate for blockage of the sun by a cloud. Although the search for new construction materials and for new approaches continues, these systems concepts are well understood. The main technical difficulties remaining are increasing the lifetime and reliability of components.

Applications and Status

Many industrial process heat applications need temperatures up to about 300°C. Parabolic troughs are ideally suited for these applications. Parabolic dishes and central receivers that can attain temperatures greater than 1,000°C can be used for large-scale electricity generation and for production of fuels and chemicals. Solar thermal systems provide heat energy that can be used directly or can be converted to other forms of energy.

A solar thermal system can satisfy a variety of needs ranging from process heat and electricity to space heating, hot water and space cooling. In some applications, heat is first used to generate electricity, then the "waste" heat is used for an industrial process or space heating. This dovetailing -- solar cogeneration as it is known -- will be put to an industrial test for the first time in 1981, when a "total energy system" is installed at a textile factory in Georgia.

Another potential near-term industrial application of solar thermal heat is for the recovery of oil. Steam produced in parabolic trough collectors or central receivers can be piped underground to release oil that is too viscous to pump out economically by any other means. This solar approach entails a double dividend, obviating the need to burn oil to produce steam and minimizing pollution.

Utilities may prove to be an important future user of central receivers or parabolic dish solar thermal systems. For facilities with more than 10 megawatts of generating capacity, the power tower is seen as the most appropriate option, while the use of parabolic dishes makes more sense in smaller utilities. Two central receiver systems, one located in Barstow, California, and another in Almeria, Spain, are under construction and will begin operation by the end of 1981. The Barstow 10 megawatt facility will be the world's largest solar power plant. In Almeria a 500 kilowatt power tower is being built next to a line focusing system of the same size. Dish systems await testing by several small utilities -- a critical venture because alternatives to small oil-fired electrical generating stations are needed.

Using solar concentrators in the production of synthetic fuels is a final important solar high-temperature application, although still in an early development stage. While no practical approaches have been developed yet, hydrogen production by thermal decomposition of water into hydrogen and oxygen is one such possibility.

The market for tracking solar collectors holds great promise, although few systems have been sold commercially, primarily because of current high cost. For the moment, most systems are being constructed in field tests, usually with federal funds.

Economics

Because high-temperature thermal systems have yet to be widely produced, any discussion of their economics is hypothetical. For instance, installed systems are available at about $200 to $400 per square meter of mirror surface, but prices are expected to drop considerably within a few years as mass production and experience establish new technologies. Thus, while the equivalent energy cost today is almost $25 per gigajoule, it is projected to fall to about $8 to $10 per gigajoule by 1990 and to $5 to $7 per gigajoule by the year 2000 (in 1980 dollars).

Private Activity

About 10 commercial manufacturers of tracking trough-concentrator systems have sold enough systems to supply about 25 thermal peak megawatts. Twenty other firms are involved in federally sponsored research on troughs, and most of these probably will be future suppliers as well. During 1980, total sales were about 50,000 square meters with a value of about $20 million. Approximately half were sold, without Department of Energy funding, to corporations and individuals eager to begin assessing the potential of solar thermal process heat systems.

Some central receiver systems and parabolic dishes are sold to the private sector, although most of them are sold to the federal government. Approximately 40 companies are involved in research on these technologies, with at least 10 preparing to sell their technology commercially.

Government Activities

The various technologies for concentrating sunlight are being supported in different ways in the federal solar thermal program and are expected to be commercially ready by the mid- to late 1980s. Troughs and fixed-reflector systems are being developed for use in industrial process heat applications and are being demonstrated in various settings. The emphasis here -- sustained through a 25 percent investment tax credit (15 percent larger than the usual investment tax credit) -- is on creating a technological base to allow development of a viable solar thermal industry. Past funding by the federal government on trough concentrators for industrial process heat has amounted to approximately $35 million annually.

Although government support of central receivers has been oriented primarily toward utilities' needs, central receivers can be used for industrial process heat too. With about $35 million per year going to this central receiver effort recently and another $35 million into the smaller dish systems for utilities and industrial cogeneration, most support has been for technology development.

Research and advanced development activities have received about equal emphasis. This investment is directed to developing lower cost, more durable and more efficient components.

Projections

Estimates of potential impacts indicate that up to 3 exajoules per year may be obtained from high-temperature solar thermal systems in the year 2000. About .4 exajoules per year of this total could be for electricity production, with the remainder for process heat applications. In this case, the installed electrical power would amount to between 10 and 15 gigawatts (depending on storage), or about 2 to 3 percent of all electrical production capability. The solar industrial process heat contribution might be about 8 percent of the total industrial energy demand, which is now about 30 exajoules per year.

To achieve these energy production levels, costs would have to be about 5 cents to 6 cents per kilowatt-hour for electricity and $4 to $7 per gigajoule for industrial process heat in the year 2000. These costs are slightly higher than average energy costs in the United States today but less than the costs of power obtained from new additions to energy capacity. The cost of heliostats, troughs and other concentrators would have to fall to about $70 to $100 per square meter in 1990 (in 1980 dollars), if high-temperature energy production levels are to be met.

SOLAR CELLS

Most solar cells that are commercially available today are made from single-crystal silicon. When first used in space satellite applications in the 1960s, the cells were very expensive. However, rapid developments in the electronics industry and intensive support of photovoltaic research and development by the Department of Energy in the past five years have substantially reduced prices. As the price of cells declined, markets for land-based applications began to develop, including remote applications where utility power is not readily available and where the alternative fuel is expensive.

Dispersed applications that are linked to the utility grid can become commercially viable by 1986. These include use of photovoltaic systems on residences, and on commercial and industrial buildings where electric power requirements are small. Alternative thin-film solar cells made from semiconductor materials such as amorphous silicon, cadmium sulfide and gallium arsenide, are under intensive research and development. These thin film solar cells offer a potential for significant price reduction to the level where photovoltaic systems could be used for electricity generation by the nation's utilities. The commercial readiness for central station utility applications is projected to occur by the 1990s.

Applications and Status

When used in centralized or decentralized applications, solar cells can meet virtually every need for electric power -- for lighting, cooling, running appliances and other basic electric power needs. Homes are likely to use flat-plate collectors, while commercial structures will use either flat plates or concentrators. Some residences already boast substantial solar cell arrays on their roofs.

The primary agricultural use for photovoltaics probably will be to power irrigation pumps. This solar application is important because irrigation alone consumes about 30 percent of an average farm's energy in the United States.

Potentially the largest markets for photovoltaic systems will be those applications that have a utility grid backup or systems used directly by the utilities to generate electricity as a part of their own generation capacity. The grid-connected dispersed market consists of small power users including individual homeowners. The ownership of these systems could be either by the users or by the utilities. Photovoltaic systems in most utility markets, those with coal and nuclear resources, will not be competitive until the 1990s.

Economics

High cost is the greatest barrier to the widespread use of photovoltaic systems. Although the price has fallen dramatically in the past few years -- from $50 to $60 per peak watt for the installed system in 1976 (about $22 per peak watt for the module alone) to $15 to $20 per peak watt today ($6 to $10 per peak watt for the module) -- today's price translates into roughly $1 per kilowatt-hour. Because conventionally produced electricity in the United States now costs the consumer between 2 cents and 10 cents per kilowatt-hour, to be fully competitive for these grid-connected applications the cost of photovoltaic power must still be reduced substantially.

It will take time for solar cell technology to capture more than its present small market share which is a portion of the electric power needs for remote sites. If the module price falls to about $2.80 per peak watt, photovoltaic systems can become fully competitive for a large part of the remote application market after 1982. Widespread use of these systems in agriculture is not expected until the late 1980s because costs need to be lower in agricultural applications for the technology to be economical.

Photovoltaic systems should be competitive for residential and commercial uses when the module price is about 70 cents per peak watt -- roughly one-tenth of today's price. The present rate of technology development and the industry's commitment both indicate that the reduction of module price to 70 cents per peak watt can be achieved by 1986. Before most utilities will find photovoltaics economically attractive, the module price needs to drop to less than 40 cents per peak watt, which it is projected to do in the 1990s. System prices are expected to be approximately three times the cell prices cited above in each year.

Private Activities

Photovoltaic research and development presently is being funded more by government than by the private sector. Yet, businesses and investors are interested in the technology -- as indicated by the increasing amounts of risk capital being ventured in photovoltaic development. About 20 companies now manufacture photovoltaic hardware for sale to the public; among them are both large corporations and small specialized companies. At least six major oil companies have photovoltaic subsidiaries with substantial activities underway in photovoltaic module and system development. By industry accounts, photovoltaic industry sales were on the order of $20 million for about 1.8 megawatts during 1979. Sales more than doubled in 1980, and approximately 50 percent of 1980 sales were in the export market.

Government Activities

The U.S. government now provides more funding for photovoltaics development than for any other renewable energy technology. In 1979, the Department of Energy spent about $110 million; that sum was increased to more than $150 million in 1980. These funds support research and development, experiments and systems testing efforts.

Two independent factors are expected to help bring down the costs of photovoltaic systems. One is progress in research and development, which can lower production costs and improve performance. The second factor is increased experiments and demonstration of specific uses in the United States, including federal experiments. This provides an additional market to encourage private photovoltaic companies to take advantage of economies resulting from mass production and to bring photovoltaic systems more directly to the attention of users. The Federal Photovoltaic Utilization Program (FPUP) was initiated in 1978. In the first two phases of FPUP (1979 and 1980) the government purchased about 3,000 small systems (most of them less than 1 kilowatt each) for the National Park Service, Forest Service lookout towers and other isolated places where small power systems are needed.

Funding for a 100 kilowatt photovoltaic system planned to provide about 30 percent of the power for a privately owned shopping center in rural New Mexico came in part from the Department of Energy and in part from the Lea County Electric Co-op. Also participating in the project are the New Mexico Solar Energy Institute (a state organization) and private solar manufacturers. This photovoltaics application illustrates a basic principle in federally funded energy programs in the United States: extensive cooperation with and participation by public and private organizations. At a cost of $2.7 million (or about $18 per peak watt), the power costs associated with this system cannot compete economically with those of conventional electric grid systems, but the system does serve as a valuable test experiment to obtain system performance and maintenance data. At the same time, along with other such projects, this system should assist the photovoltaics industry by helping to reduce per-unit manufacturing costs.

Projections

The United States has a diverse program aimed at bringing down the costs of photovoltaics and at helping the industry develop additional markets for solar cells. Specifically, the goal is to bring the current price of an installed system from $15 to $20 per peak watt down to about $6 per peak watt by 1982, $2 per peak watt in 1986 and $1.25 per peak watt by 1990-2000. (These figures are in 1980 dollars.) The primary uses for systems projected to become cost-effective in 1982 will be those at remote sites in the United States and in the international market. In 1986, applications in residences are projected to become economical; after 1990, utilities are projected to find their applications cost-effective.

If the cost projections can be reached, estimates of primary energy impact up to 1 exajoule per year by the year 2000 have been made in some photovoltaic industry studies. This could include .3 exajoules in the residential sector (about 2 million systems installed), .04 exajoules in the commercial sector (approximately equivalent to the production of one 850 megawatt fossil fuel electrical-generating plant), .5 exajoules in industry, .01 exajoules in agriculture and .2 exajoules in utilities.

BIOMASS ENERGY SYSTEMS

The United States has extensive biomass resources available to help meet a significant part of its energy needs. Most estimates indicate a potential of 5 to 15 exajoules per year. Biomass currently provides more than 1.5 exajoules of energy -- more than 2 percent of the total U.S. energy consumption. The major portion of this energy is used for process heat and electricity generated by the forest products and paper and pulp industries. Recent estimates indicate that the conversion of unused agricultural and forestry residues, and noncommercial timber could provide 6 to 10 percent of the nation's energy needs on a sustained basis. Intensively managed growth of terrestrial and aquatic biomass crops on "energy farms" could increase the biomass contribution to about 16 percent of current U.S. energy needs. The long-term projection for the use of biomass in the United States is at least 10 exajoules annually.

Applications and Status

In homes, biomass (primarily in the form of wood) is used extensively for heating. More than 3 million U.S. homes (most of them in the northeast, southeast and northwest) currently use wood to provide some of their space-heating needs. Sales of wood stoves exceeded 1 million in 1980. Improvements in wood-burning devices, such as fireplace inserts and heaters with controlled combustion, are making wood an increasingly attractive resource.

In commercial buildings, energy derived from biomass is not expected to be widely used, although some uses may prove applicable and economical.

Two particularly promising technologies for agricultural use are anaerobic digestion (which converts manure into medium-energy gas) and fermentation (which converts crops and crop residues into liquid fuel). Both technologies are being used extensively in other countries. Alcohol fuel produced on the farm from farm residues and crops could displace petroleum used for transportation and irrigation. Oil from seeds is another promising option, because some seed oils can be used as diesel fuel.

In industry, forest residues currently supply almost half the electrical and process heat needs of the forest products industry. As the cost of competing fuels increases, such applications will expand and spread to other industries. Even now, the forest products industry uses about 1.5 exajoules per year of biomass, which is by far the largest use of any renewable resource except hydro power.

In some industries that have large amounts of a biomass residue, gas produced from biomass now is being used in boilers previously fired by oil or natural gas. Without being upgraded, this gas lowers boiler output by 5 to 10 percent and cannot be economically transported great distances. But, if the price of fuel oil and natural gas increases, industries with access to biomass wastes may turn increasingly to gas from gasifiers.

Another prospect for industry and agriculture is using an upgraded gas (containing about 2 to 3 times the energy of the gas coming from the gasifier either as a fuel or as a "synthesis gas") to produce synthetic natural gas, methanol or synthetic gasoline. This upgraded gas can be transported economically and substituted for petroleum or natural gas without lowering a boiler's output.

Like industries, electric utilities that now burn natural gas or oil could (with only a small reduction in power capability) use a gas derived from biomass. Upgraded, this gas can be transported through existing pipelines -- a fact of some importance to natural gas utilities. But apart from isolated experiments, biomass-generated gas is not now used by natural gas utilities.

So far, gas derived from biomass is not the cheapest energy alternative -- wood and wood residues are more promising for electricity generation. In particular, wood chips or pellets can be used in some coal-burning utilities with only minor modifications (although wood burning is more efficient in facilities originally designed for that purpose). About five small utilities in the United States currently use wood to generate electric power, and more are considering it as a possibility.

Private Activities

Private biomass-related activities are too extensive to catalog here, although some generalizations are possible. The wood-stove industry has grown greatly in the United States during the past decade as Americans have rediscovered the advantages of the fireplace and stove. (The sale of stoves alone now totals about $500 million annually.)

Private activity also has been substantial in the production of ethanol from corn, potatoes and other crops. Nationwide, an estimated 100 million gallons of fuel-grade ethanol is being produced by hundreds of companies, and plants either under construction or planned soon will expand that figure.

Several small companies also have ventured into the business of making and selling anaerobic digestion systems. So far, however, their combined sales do not exceed $1 million.

While many new biomass technologies hold great promise, almost all of the 1.5 exajoules that biomass contributes to U.S. energy needs is accounted for by the forest products industry, which burns its wastes in boilers. For use in such boilers, the industry developed pellet-making equipment for which a market is now developing. Approximately a dozen plants now are making pelletized biomass from agricultural and forest wastes, and many more are in the planning stage.

Government Activities

Federal support for biomass development (including alcohol fuels development) has increased in the budgets of the departments of Energy and Agriculture. The technologies and processes include direct combustion and gasification and liquefaction of wood and wood residues (as a source of industrial process heat, electricity and residential heat), the production of ethanol for gasohol, anaerobic digestion of manures to produce gaseous fuel and direct combustion of agricultural residues for use in agriculture.

However, federal program efforts in biomass are expected to be directed toward long-range research and development support for advanced technologies to produce alternative fuels and petrochemical substitutes.

Government work on the development of the longer term biomass technologies consists primarily of sponsoring basic energy research and proof-of-concept experiments. Among the biomass technologies expected to contribute to U.S. energy needs after 1990 are energy farms and thermochemical-conversion facilities for producing gas and fuel oil from various cellulosic feed materials (such as wood, corn stalks, and municipal organic wastes). Expected to become commercial even later are aquatic energy farms, the cultivation of non-traditional energy-rich plant species, biophotolysis (direct production of hydrogen) and other advanced conversion technologies.

The activities of the other federal entities involved with biomass are diverse. The Tennessee Valley Authority, the largest publicly owned utility in the nation, has a no-interest loan program for residential wood stoves in part of its service area. Several states also have active biomass support programs, especially for ethanol production.

Projections

Although often not considered in U.S. energy accounting, biomass currently provides approximately 1.5 exajoules (2 percent) of the nation's yearly requirements. If the federal biomass program is successful, another .5 to 1.5 exajoules per year will be added before 1985 through the direct combustion of biomass or its conversion into gaseous and alcohol fuels. It is hoped that almost 2 billion liters (500 million gallons) per year of alcohol fuels alone will be produced by 1981, resulting in about 20 billion liters (5 billion gallons) of gasohol. An additional 6 exajoules per year could easily be available before 2000, as biochemical and thermochemical conversion technologies are improved. After 2000, contributions from the innovative land-based and aquatic energy farms now under research might push that total to more than 8 to 10 exajoules per year.

WIND ENERGY SYSTEMS

Electric power generation is probably the principal application for wind systems in the United States, but water pumping and mechanical applications also are practical and efficient. In the United States, smaller electrical systems (1 to 100 kilowatts) are expected to be employed on site for residential and farm uses; intermediate-scale systems (100 kilowatts to 1 megawatt) for large farms, irrigation systems, small utilities and remote communities; and large systems (greater than 1 megawatt) for electric utility and industrial uses.

Increasingly, wind power is viewed as economical in the numerous locations where the average wind speed is high. Most wind systems and components can be built from readily available materials and can be used in either centralized or decentralized applications. The price of wind power is expected to fall as advances are made and wind machines are mass produced.

Applications and Status

Today, most sales of wind machines are to rural residences and farms. The total number of new machines sold since the renewed interest in wind energy began in the early 1970s is estimated to be only a few thousand in these two sectors. However, interest and sales are rising rapidly each year as improved machines are being marketed. More than 50 utilities have research projects in wind energy, and a few have incorporated wind machines into their electricity-generation systems. For example, the Southern California Edison Company has installed a 3.5 megawatt horizontal-axis system and a 500 kilowatt vertical-axis system at its own expense. Similarly, Hawaiian Electric has contracted with a private firm to supply the utility with 80 megawatts of wind-generated power, and Pacific Gas and Electric in California is interested in buying about 100 megawatts from another firm.

Wind energy has found only a few uses in commercial or industrial establishments because business and industry tend to be located primarily in urban areas where buildings may block the wind, institutional problems exist and utility power is readily available.

Economics

Wind machines of all sizes are expected to become fully cost-competitive with non-renewable power systems in the mid-1980s, particularly in remote areas. Improved technology and more efficient production are expected to reduce the present capital costs of wind systems by at least one-half in the 1980s. The energy cost of 3 cents to 4 cents per kilowatt-hour, reported now for a few high-wind sites, should become commonplace for advanced large machines.

Several federal actions strongly affect the economics of wind machines for non-utility use. Residential wind machine owners receive a 40 percent federal income tax credit (plus an additional credit in some states), while businesses can get an investment tax credit of 25 percent (an additional 15 percent more than the usual 10 percent investment tax credit) for investing in wind machines. Moreover, under the Public Utility Regulatory Policies Act (PURPA), any wind machine owner can sell excess power to the local utility at a fair rate, as the private companies selling wind-generated power to Hawaiian Electric and Pacific Gas and Electric are now doing.

Private Activities

The private sector is very active in wind energy development. In the United States, about 35 concerns are manufacturing small-scale wind electric systems, six are producing medium-scale electric systems and four are fabricating large-scale electric systems. In addition, four companies are producing mechanical wind machines, largely for water pumping. Sales are small although rapidly growing: about $10 million to $15 million in 1980 sales of small and large machines totaling about 5 megawatts of capacity. More than 90 private groups are involved in wind energy research.

Many small, enterprising companies with innovative ideas have been active in the small wind system market during the past 10 years. For example, one company's first effort was to have its employees travel the back roads of the midwestern United States buying windmills left over from the 1930s. The company then refurbished, improved and resold the machines.

During the past five years, a large number of companies have joined the wind energy business. Large aerospace companies, for instance, have been participating extensively in the federal wind program, as well as investing their own funds for research and product development. The "wind farm" companies -- those planning to erect clusters of wind machines at particularly good sites and selling the energy to utilities -- also may become an important part of the industry.

Government Activities

The federal government has spent more than $100 million since 1975 to develop wind energy technology, mostly for horizontal-axis machines. About 60 percent of the 1981 wind budget is earmarked for engineering development and wind-machine testing. Funds also supported research and analysis, technology development and the study of wind characteristics.

Although the Department of Energy wind program involves all sizes of wind machines, a major percentage of the funds is used to develop larger machines because they are inherently more expensive to design and test and thus a high risk venture for private companies. Managed by the National Aeronautics and Space Administration, the large-machine program has focused on erecting progressively larger wind machines. Under its auspices, four 200 kilowatt systems are being tested: one in New Mexico has operated more than one year; one off the New England coast has supplied up to 50 percent of an island's power on windy, winter nights. A 2 megawatt turbine recently brought into operation in North Carolina is the world's largest (its rotor is 68 meters in diameter). Three even larger machines with 90 meter diameters and ratings of 2.5 megawatts are scheduled to be operated as a three-machine cluster starting in 1981 in the state of Washington. These latest machines are expected to be cost-competitive for utility applications by the mid-1980s. In all, more than 10 megawatts of wind system capacity will have been installed by the Department of Energy by late 1981.

The Department of Energy's small wind machine program has been testing commercially available small machines. A test center in Colorado can test up to 18 small systems simultaneously. Federally funded Sandia National Laboratories in New Mexico has primary responsibility for developing vertical-axis advanced wind machines. The Solar Energy Research Institute in Colorado manages the research and development activities in the wind program.

Other agencies are also active in wind system development and commercialization. The Department of Agriculture has a major responsibility for developing small machines for rural use. The Water and Power Resources Service has initiated a large project in Wyoming that couples wind and hydro power resources.

Projections

According to a published study by the Domestic Policy Review Panel for Solar Energy in 1979, wind power applications in the year 2000 could provide up to

1.7 exajoules or about 2 percent of our total energy demand by the turn of the century. In both the public and private sectors, wind energy is rapidly being developed and commercialized. Wind energy already is cost-competitive in many specialized applications. Stimulated by economies resulting from mass production, by the manufacture of larger machines and by technological advances that contribute to greater reliability, the wind industry could well enjoy a boom in the future.

OCEAN SYSTEMS

Energy conversion systems for utilizing four different ocean energy resources are being developed in the United States. Under development are systems for ocean thermal energy conversion (OTEC) and for harnessing wave energy, ocean currents and salinity gradients. The OTEC concept is based upon the exploitation of the temperature differences between warm surface water and cold subsurface water (1,000 meters or more in depth) to operate a heat cycle (Rankine cycle) that generates electricity.

Although the OTEC technology is receiving the bulk of the funding in the U.S. ocean systems program, research and development is underway on technologies for the extraction of kinetic energy from waves and currents and for conversion of energy from salinity gradients.

As envisioned in the United States, commercial OTEC plants are expected to be most economical in the 100 to 500 megawatt range. However, smaller plants (5 to 100 megawatts) may become commercially viable for certain applications. Small plants for island site deployment are, in fact, being designed by engineers in the United States and other countries.

Applications and Status

The ocean energy resources adjacent to the United States mainland are significant (such as the Gulf of Mexico and the Gulf Stream off the U.S. eastern coast), and there are many locations near islands where good thermal differences are present close to land (Puerto Rico, Virgin Islands, Hawaii and Guam). Thus, the OTEC program is developing technology and systems aimed at floating plants in tropical and subtropical waters and near-shore and onshore plants for deep-water sites adjacent to the U.S. mainland, islands and territories.

There are two key applications of OTEC technology. The first is to produce baseload electricity offshore, then transmit it via a submarine electrical cable to utilities, industries and other onshore users. The second is to manufacture energy-intensive products such as hydrogen, ammonia and aluminum aboard cruising OTEC "plantships." (Hydrogen would be derived from the electrolysis of water; nitrogen would be obtained from air liquefaction and combined with hydrogen to synthesize ammonia.) Hydrogen or ammonia can be transported for subsequent production of electricity using fuel cells. There is an increasing world demand for ammonia as a fertilizer, and both hydrogen and ammonia will find applications as fuels and chemical feedstocks. Both floating plants near shore (up to about 200 miles) and land-based plants are under consideration in the ocean thermal program planning for the mid- to late 1980s.

For cable-connected applications, the best U.S. OTEC sites appear to be in Hawaii, Puerto Rico, the Virgin Islands, Guam and the Gulf Coast states. The islands are choice locations, because the available ocean thermal differences are considerably greater there than near the Gulf Coast and the appropriate ocean thermal resource is often within 1 to 9 kilometers from shore so that relatively short underwater electrical transmission cables are necessary. (Along the Gulf Coast, the suitable resource is more than 100 kilometers from land.) In some cases, the OTEC plant can be land-based, which may reduce development risks and further improve OTEC's economics. A key factor in the early commercial development of island-based OTEC power plants is that the islands now get almost all of their power from expensive imported oil. Thus, OTEC-produced baseload power may well be economical for the islands by the early 1990s.

Economics

Among the ocean energy options, OTEC is technically ready and a 10 to 40 megawatt pilot plant could be demonstrated in the mid-1980s. Mature, cable-connected, closed-cycle OTEC plants are being projected in OTEC system application studies to become commercially available at a capital cost ranging from $2,500 to $3,000 per kilowatt (in 1980 dollars) by the late 1980s. Although baseload OTEC plants might be 50 to 100 percent higher in installed system capital costs per kilowatt of power capacity compared to coal or nuclear power plants, they are not subject to escalating fuel costs throughout their operative life, unlike non-renewable power systems in which fuel costs can become the dominant factor in the future price of generated power. Hence, even early commercial OTEC plants are expected to be competitive with existing oil plants when life-cycle costs are considered, and advanced plants may be competitive with coal-fired plants.

Technologies for utilizing ocean currents, wave and salinity gradients are in early stages of development, and convincing economic projections cannot yet be made. It seems apparent, however, that a major factor in the cost of energy from ocean current and wave systems will be mooring costs.

Private Activities

Completely funded by non-federal sources, the 50 kilowatt "Mini-OTEC" was successfully demonstrated off the coast of Hawaii in 1979. With its total cost of $3 million contributed by industry and the state of Hawaii, this facility generated as much energy as previously predicted, assuaged fears about possible operating and environmental problems and aroused considerable private sector interest in OTEC.

More than 200 companies are conducting government-funded OTEC research. Some are large corporations long involved in the construction of conventional power plants. Others include marine and offshore oil companies. Many of each type are investing their own funds, in some cases in significant amounts.

Private companies have been the leaders in ocean wave and ocean current research. Several large companies, as well as individual inventors, have made significant investments before seeking government funds to continue their projects. In addition to research, the private sector established an OTEC Utility Users Council and the Ocean Energy Council in 1979.

Government Activities

The federal ocean energy program was funded in past years at about $40 million annually. About 95 percent of this funding is being used for OTEC development. An engineering test facility, OTEC-1, was deployed in 1981 about 30 kilometers off the Kona Coast of Hawaii on a converted tanker to test components in an ocean environment. The facility can test components at sizes up to 1 megawatt.

Because Hawaii, Puerto Rico, the Virgin Islands and Guam offer the best U.S. prospects for early commercialization, the Department of Energy pursued an "island" strategy for early demonstrations. The strategy could result in commercial OTEC plants of 40 to 200 megawatts being constructed for the islands by 1990.

The U.S. Congress passed legislation in 1980 establishing national demonstration, commercial targets, simpler licensing procedures, and maritime loan guarantees.

Projections

As expressed in recent legislation, the U.S. commitment to obtaining energy from OTEC amounts to 10,000 megawatts (or .7 exajoules per year) by the year 2000.

HYDRO POWER

Most of the largest hydro power sites in the United States have been developed, and many of the remaining sites are in environmentally protected areas and national parks. In view of this fact and because of the recent rise in the cost of energy, interest is growing in developing smaller sites, especially those where hydro power equipment can be added to existing dams.

Hydro power is one of the two renewable energy sources already contributing significantly to the national energy budget. (Biomass is the other.) Conventional hydro power capacity in the United States now stands at about 65 gigawatts -- nearly 3×10^{11} kilowatt-hours annually, more than 3 percent of total U.S. energy demand and more than 12 percent of all electricity needs. About 90 percent of this capacity is in large plants (30 megawatts or larger).

Present capacity represents a five-fold increase in 40 years. The greatest growth has occurred in federally owned plants, which now produce half of U.S. hydroelectricity. Investor-owned utilities control one-fourth, and the rest of the capacity is that of rural electric cooperatives, municipal utilities and industrial concerns.

Technologically and commercially mature, hydro power possesses a secure industrial and financial base for expansion. It has an assured share in future energy production, though the present capacity can be expanded only to a limited degree. The limits of its role as a future energy source probably will be determined by the success with which a balance is struck among many competing demands for water resources, such as for irrigation or flood control.

Applications and Status

Nearly all hydro power in the United States is fed to electric utility networks, where it is blended with power from other fossil- or nuclear-fueled generation facilities to serve the entire spectrum of electrical energy uses. Because hydro power output can be adjusted quickly and easily to meet changing demands, electric companies commonly use it to supply the extra power needed during demand peaks. Where hydro power is plentiful and when streamflow is high, it is also used to supply baseload electricity for longer periods.

The Public Utility Regulatory Policies Act, recently passed in the United States, encourages the interconnection of small-scale hydro power plants and utility networks. This new law requires utilities to buy hydroelectricity at the utility's avoided cost -- the cost the utility would otherwise incur by generating this additional energy itself. This act became effective in 1981, and it is too early to predict its effect on future hydro power applications.

Hydro power bears a special relationship to some power-intensive industries. In particular, major hydro power facilities have a long-standing place in the electrolytic and electrothermal refining of metals. In the future, more hydro power sites distant from centers of concentrated electricity demand may be paired with plants that manufacture energy-intensive products such as fertilizers and aluminum.

Economics

The costs of developing hydro power sites vary widely, depending upon distance from centers of demand and other economic factors. The largest cost is that of the dam, which typically accounts for about 80 percent of total development costs. For instance, this varies greatly with the site and is related to the economics of other uses of water resources. The same water resource can be used for irrigation, municipal and industrial water supply, transportation, flood control, waste disposal, fisheries, wildlife, recreation and the support of the ecosystem dependent upon the streamflow. While this multiple use is economically advantageous for hydro power, it also involves major constraints on hydro power production. Multiple use also accounts, in part, for the federal government's involvement in so many hydro power developments, because the government has interests in water resource development and management other than energy.

Because the capital cost of a hydro power installation is the chief determinant of the cost of the energy harvested from it, and because the costs of operating and maintaining hydro power facilities are low, the cost of borrowing money is a major factor in the economics of hydro power. Consequently, measures that affect the cost of money -- such as investment tax credits, loan guarantees and federal financing -- play an important part in determining the feasibility of new hydro power developments.

One economic factor not yet resolved is that of capital depreciation. Rivers are permanent but reservoirs are temporary -- sediment ends the economic life of those reservoirs that cannot be cleaned. Because most of the nation's great reservoirs are still relatively new, the problem of their depreciation has not been resolved. Until this problem is dealt with, hydro power cannot truly be called an inexhaustible energy source.

The economics of small-scale hydro power are less certain than that of larger facilities. Emphasis in the United States so far has been on rebuilding abandoned hydro power sites and on adding hydro power generators and equipment at existing dams. Federal incentives are offered in the form of low-cost loans for feasibility studies, tax advantages for investors and guarantees that utilities will purchase energy produced in small hydro facilities. Recent evaluations suggest that existing dams capable of supporting installations of 1 megawatt or more capacity will be economical. Projections of 8 gigawatts for small-scale hydro power will require investments -- mostly of local capital -- of perhaps

$10 billion to $20 billion by 2000; if these investments are made, present hydro capacity will increase by about 15 percent.

Private Activities

About half of all hydroelectric capacity (including that under construction) is not federally owned. Projects scheduled for completion by 1990 will add to the non-federal sector another 12 gigawatts of capacity, of which nearly half will be owned by investor-owned utilities. Hydro power generation in these new non-federal facilities will be about .34 x 10^{11} kilowatt-hours per year of which about 40 percent will be by investor-owned utilities.

Within the private sector, additions to capacity rather than to generation indicate that hydro power will be increasingly devoted to peak loads that command higher energy prices. Accordingly, within the non-federal sector, the average percentage of capacity utilized is expected to drop from the present 54 percent.

By the end of the century, the non-federal capacity is expected to exceed 50 gigawatts, with annual generation of more than 2 x 10^{11} kilowatt-hours. Because of the long time lag involved in hydro power development, and because hydro power will always be used even if other sources are cut back, these estimates are considered relatively firm.

In the development of small-scale hydro power, private sector activity is still relatively small. Most demonstrations have been requested by state, municipal and cooperative organizations, which are given preference in financing. However, the Federal Energy Regulatory Commission (FERC) has received about 500 new license applications for small-scale hydro facilities out of an estimated 5,000 dam sites that are potentially suitable for development. The growth rate in receiving these applications has been very rapid; half were received in the last three months' reporting period of 1980. Of the preliminary permit applications (totaling 7.3 gigawatts), more than 40 percent were less than 30 megawatts and less than 30 percent were larger than 100 megawatts. The trend toward smaller size units in the United States is clear, because existing small hydro facilities comprise only about 10 percent of the total installed capacity. Many investors have committed capital, and several equipment manufacturers have developed equipment especially designed for small-scale hydro power applications.

Government Activities

The federal government controls about 32 gigawatts of hydro power capacity. It has created organizations that design, construct and operate hydroelectric facilities and market the energy. In general, the Army Corps of Engineers is the chief builder and operator of federal hydro power installations. In the western United States, the Water and Power Resources Service of the Department of the Interior is responsible for constructing multiple-use water resource developments, primarily to support irrigation and only secondarily to generate hydro power. The Tennessee Valley Authority (TVA) and Water and Power Resources Service have the authority to construct and operate their own power facilities and to market the power. Five regional administrations of the Department of Energy sell federally generated hydro power to utilities and industries.

Through the Federal Energy Regulatory Commission (FERC), the federal government regulates and licenses the construction and operation of most hydro power installations. FERC exempts small-scale plants (smaller than 5 megawatt capacity) from certain regulations and simplifies licensing procedures for them.

In various ways, all these agencies are working to expand large-scale hydro power capacity. New construction projects have been approved and construction funding appropriated by the Congress for about 7.5 gigawatts of additional capacity, and feasibility and design studies are underway on an additional 7.5 gigawatts of capacity. A further increase in capacity is expected as improvements are made in existing facilities to upgrade their capacity.

Projections

The United States probably will have about 100 gigawatts in hydro power capacity by the year 2000. This represents growth of approximately 50 percent, or about 2 percent per year, for the next 20 years. For large-scale hydro power, the projection is not likely to change greatly, partly because so much time elapses between carrying out initial feasibility studies of a major site and completing the project. The total hydro power capacity available for development after the year 2000 appears to be less than 100 gigawatts.

With respect to small-scale hydro power, the present federal program objective is to assess the potential of this resource as a contribution to U.S. generating capacity. Substantial disagreement remains as to what that capacity may be. The projection suggested by the Domestic Policy Review of Solar Energy, 8 gigawatts, is intermediate between low and high estimates ranging up to 20 gigawatts. (Existing small-scale hydro power applications total more than 3 gigawatts.) However, until the uncertainties about the effectiveness of developmental incentives are resolved and environmental and other barriers are surmounted through research and experience, it is impossible to establish a definite projection for small-scale hydro power development.

GEOTHERMAL

The greatest potential for hydrothermal development, particularly for electric power generation and direct heat applications that require relatively high temperatures, lies in the western United States. On the Atlantic Coast and in the southeast, prospective sites for hydrothermal development are associated with low-to-moderate-temperature reservoirs. Known geopressured resources are located primarily along the Texas and Louisiana Gulf Coast, but there is evidence of geopressured systems in deep sedimentary basins elsewhere in the United States. Hot-dry rock resources are widespread in the western states and may exist also in the eastern states.

At present, the worldwide installed geothermal electric capacity is about 2,500 megawatts, including about 30 percent of it in the United States.

Applications and Status

Electric power can be produced reliably at competitive costs from hydrothermal resources hotter than about 150°C. Already, 912 megawatts of electricity is being commercially produced at The Geysers geothermal steam field in California, and electric power development using hot water reservoirs has begun at two sites in California's Imperial Valley. U.S. utility companies have announced their intentions to build hydrothermal electric generating plants to produce additional generating capacity totaling more than 1,000 megawatts. Several municipalities have begun to develop geothermal energy for public use, and some large industrial users who own or lease land containing geothermal resources are evaluating those resources in view of their own needs for electricity.

About 115 thermal megawatts of hydrothermal direct heat is being used in a dozen western states for space heating and for industrial and agricultural processes. The principal direct geothermal heat users are energy-intensive industrial firms, municipalities, school districts and hospitals (which use geothermal energy for space heating). These lower-temperature applications are widely distributed across the country.

In agriculture and aquaculture, the direct use of hydrothermal energy applications is increasing. Geothermal energy is being used to heat process water in an ethanol plant in Colorado; a similar use is planned for a geothermal industrial park in eastern Oregon. In South Dakota, the Diamond Ring Ranch extracts energy from a low-temperature geothermal resource to heat farm buildings, dry grain and warm drinking water for the ranch's livestock. Geothermal fish hatcheries are operating in California, Colorado, Idaho, Oregon, Utah and Wyoming. The use of warm, clean geothermal water year-round enhances the growth rate and improves the taste of the fish. Fish Breeders of Idaho has grown catfish in geothermal water for more than six years -- of particular interest because Idaho's climate is too cold and the growing season too short to operate a fish farm without benefit of heated water.

Geopressured energy use is best viewed as a mid-term energy option. Tests of prototype production wells in Louisiana are to be made through 1985. If they show that the technologies are feasible, commercial development of geopressured resources could begin in 1987. In contrast, extensive use of hot-dry rock resources through water injection is a long-term prospect, although tests are already underway. A 5 megawatt thermal loop has been in operation in New Mexico, and energy extraction experiments there and at a second site should be completed by 1987. Geopressured technology demonstration activities could begin in 1988, followed by commercial deployment of hot-dry rock technology around 1990.

Private Activities

Private organizations so far have played a major role in developing geothermal energy. The largest geothermal project in the world, the electric power complex at The Geysers in California, was initiated and developed privately. However, similiar high-temperature, dry-steam hydrothermal resources are rare in the United States. The more abundant liquid-dominated hydrothermal resources involve higher risks and costs, which inhibit their rapid private development.

A 10 megawatt electric plant in southern California, which was tested at the start of 1980, is the first U.S. plant to generate electric power from a liquid-dominated resource, and the first geothermal plant of substantial size in the world to utilize a two-working fluid process. Two other 10 megawatt electric plants will be completed in California before the end of 1981.

Most geothermal engineering companies are small, special-purpose engineering concerns that pioneer plant design concepts or plant components. But some large architectural and engineering firms also are involved in designing and building major geothermal plants. These engineering companies see themselves as technical bridges between the developer and the final user of the geothermal energy resource. Although most prefer to limit their role to design and construction, some have marketed geothermal energy to users (most frequently utilities) and a few have underwritten project risks.

Recently, small and medium-sized firms specializing in geothermal exploration, engineering, and support services have entered the field. Manufacturers of energy-conversion equipment now sell turbines, heat exchangers and other hardware designed for geothermal service. Most of the major energy companies are becoming involved in the development of geothermal energy in one form or another. The main objective of these energy companies is still the production of steam for electric power. They have shown little interest in direct heat applications, primarily because most such projects are small.

Government Activities

Department of Energy support for geothermal energy development has been approximately $155 million to $160 million per year for the past three years. Another $16 million to $19 million each year has been spread among the seven other member agencies of the Interagency Geothermal Coordinating Council -- chiefly the departments of the Interior, Defense, and Agriculture, and the Environmental Protection Agency.

The overall objective of the geothermal program is to transform the many types of geothermal resources into an array of technically, economically and environmentally sound commercial ventures. The program aims both to remove barriers to the immediate industrial development of resources that are now potentially economical and to ensure the mid-term and long-term development of resources with uses technically and economically less certain. The program features research and development projects directed at reducing the costs of technologies as well as providing financial incentives (including the Geothermal Loan Guaranties Program) aimed at sharing the private developers' front-end risks in exploiting new geothermal reservoirs.

The Department of Energy's program can best be described in terms of the five modes of using geothermal energy to advantage. It encourages the use of high-temperature hydrothermal resources for electric power generation. Technologies for exploiting hydrothermal resources for electricity are available and cost-competitive, and they are being used today on a limited scale. The federal program's emphasis is on accelerating industry's exploitation of the resource base. to this end, the government provides tax incentives and loan guaranties, it sponsors applied research and development to resolve critical technical problems, and it assists in the confirmation of new reservoirs. The federal program also includes support for full-scale demonstration projects. For instance, a 3 megawatt electric wellhead generator system is scheduled to begin operating in 1981 near Puna, Hawaii, and a commercial-scale 50 megawatt electric flash-steam demonstration plant is expected to be operational in 1982.

Other federal programs focus on using moderate-temperature hydrothermal resources for electric power production. A much more widely available resource than high-temperature hydrothermal, moderate-temperature hydrothermal systems require the development and demonstration of binary-cycle electric power generating systems (those based on the use of a turbine generator driven by an organic working fluid). The government's program for developing this resource is designed to bring the technology to maturity and economic competitiveness by about 1985. Specifically, it entails research and development directed at reduction of development costs, confirmation of reservoirs, and plant demonstrations. (A 5 megawatt electric binary-cycle power plant in Idaho will begin operation in 1981, and a 50 megawatt electric binary-cycle demonstration plant is scheduled to be constructed in California.)

Government programs also supported the use of hydrothermal resources (at all temperatures) for direct heat applications. Technologies for using geothermal energy directly for space heating and for process heat are well developed and economical, though more work is needed to identify reservoirs close to areas where they can be used. To stimulate independent industrial activity, which is just beginning, the federal geothermal program supported direct-use demonstration projects, reservoir confirmation activities, financial incentives and risk sharing, technology transfer (through regional technical assistance centers), the reduction of legal impediments to development, and research and development to reduce costs and increase reliability. Twenty-two cost-shared direct heat demonstration projects are now underway, most of them for space conditioning and district heating applications.

The federal program provides for use of geopressured resources -- primarily methane, but also thermal energy for electric power production and direct heat applications. The Gulf Coast oil and gas industry is expected to develop this resource if production is demonstrably economical. Current program activities center on assessing the technical performance and economics of these resources through extensive tests of both existing wells and new, specially designed wells.

The final mode of geothermal energy covered in the federal program is the hot-dry rock resource. The technology for exploiting the enormous heat content of dry geothermal resources is under development and has been proven technically feasible on a pilot scale at one site. Some of the current program emphases are on research and development aimed at improving the energy-extraction technology, on reservoir engineering and on the economics of exploiting hot-dry rock resources. Another emphasis of the program is to develop a second test site, one with geological characteristics different from the first.

Projections

Surveys of the geothermal industry's intentions indicate that about 2 gigawatts of geothermal electric power capacity will have been installed in the United States by late 1985. Some 65 percent of this would be at The Geysers, while the remainder will be at liquid-dominated hydrothermal reservoirs in the western United States.

The Interagency Geothermal Coordinating Council geothermal market projections for 1985 forecast a total of .4 exajoules per year, which would be about .5 percent of total U.S. energy production. Of this total, about two-thirds is expected to be in electric power production with most of the rest in direct heat applications.

Geopressured resources in the United States are known to contain enormous amounts of energy. If the results of current research are favorable and the environmental impacts can be minimized, rapid commercial exploitation of these resources should occur, beginning in the mid-1980s. While the forecast for methane production by 1985 is low, by the year 2000 about half of all geothermal energy is projected to come from geopressured methane -- a total of perhaps 3 exajoules per year, or more than 3 percent of the annual U.S. energy production. By the year 2000, about 2 exajoules per year is projected to be in electrical applications from hydrothermal sources and about 1 exajoule per year in direct thermal applications. In short, contributions from these two energy sources are projected to grow by factors of eight to 10 between 1985 and 2000.

Even greater quantities of energy are believed to be present as heat in hot-dry rock formations. As yet, however, the locations and characteristics of these formations are not well known and the techniques for extracting the heat are not fully developed. With available technical knowledge, it is not possible to determine whether the cost of recovering energy from hot-dry rock resources will be low enough to permit their exploitation by industry. If it is, commercial development may begin in the 1990s.

OIL SHALE

The United States has some 1.8 trillion barrels of oil in oil-bearing shales in three western states: Colorado, Wyoming and Utah. About one-third of this oil from shale is believed recoverable from 43,000 square kilometers of these lands. The shales range in quality from about 40 to more than 300 liters of oil per metric ton of rock. (This is equivalent to about .3 to 1.8 barrels per metric ton of rock.) The richest layers of the deposits are more than 30 meters thick; together, lean and rich sequences of shales are more than 500 meters thick in Colorado.

Comparing U.S. shale resources with world reserves of conventionally available oil helps put the scale of the resource into perspective. The 600 billion barrels recoverable from western oil shale compares to 350 billion barrels in the Middle East oil reserves, and is estimated to be about equal to the known world reserves of oil recoverable by conventional methods of drilling and pumping. These estimates change periodically, however. New discoveries, such as those in the North Sea, the Soviet Union, China and Mexico, have helped push the world oil reserve tally upward in the past several years.

Economics

Historically, the cost of producing oil from shale has been higher than the value of the oil. Depending on which extraction processes are used, oil from shale is now estimated to cost from $32 to $62 per barrel with a 12 to 15 percent return on investment. The capital investment required ranges from $1.7 billion to $2 billion for a facility able to produce 50,000 barrels per day. In addition, operating costs amount to tens of millions of dollars annually.

Barriers and Impacts

Significant barriers stand in the way of a commercial-scale oil shale industry. Because shale deposits are in remote locations, developers will have to build new towns, roads, airports, railroads, electric power plants, water supply and transportation facilities, power lines and communication systems at costs of hundreds of millions of dollars. Also, there is a scarcity of skilled craftsmen and technical workers needed to construct, operate and maintain the oil shale plants. Firms with the necessary design capabilities have long backlogs of work for other technical projects, including facilities for producing other synthetic fuels, and for gasifying and liquefying coal.

Controlling the pollution of air and water is a major concern because of the immense volume of materials involved. Mining 1 million or more metric tons of shale each day, disposing of the waste after the oil is extracted and stabilizing and reclaiming the area where the waste is deposited pose major technical, financial, environmental and logistical challenges. Just one surface retorting plant with a 50,000 barrels per day capacity will require disposal, stabilization and reclamation of almost 20 million metric tons of waste rock each year. Other serious problems are the disposal of relatively small amounts of waste water containing organic constituents, pollution caused by the materials handling equipment and pollution caused by the sulfur compounds contained in the spent shale.

Availability of water supplies may be a constraint. At present, water can be found for production equaling only several hundred thousand barrels per day, so water-development projects will be needed. Each barrel of shale oil will require from two to seven barrels of water, depending on which process is used. In some processes, water may be recycled and used again; but even so, ensuring that adequate water supplies are available will be a problem in western regions, where competition for water is already intense.

Most discussions of the social impacts of oil shale development center upon the need for new communities to house thousands of workers, their families and the others attracted to the business opportunities associated with this type of development.

<u>Private Activities</u>

Nearly every major American oil company has a financial interest in shale oil. Some own shale lands and others are actively developing retorting and refining technologies. Some of these companies are entering into commercial ventures where the feasibility studies have been partially funded by the federal government.

The most ambitious private endeavors include the development of four 2,100 hectare prototype tracts in Colorado and Utah. One tract -- the site of an in situ pilot operation since October of 1980 -- is being developed by Rio Blanco Oil Shale Project, a joint venture of Standard Oil of Indiana and Gulf Oil Company. Rio Blanco hopes to develop a large open-pit mine with surface retorts which will produce 78,000 barrels of shale oil daily by 1987. The second Colorado tract, being co-developed by Occidental Petroleum and Tenneco, provides a testing ground for the modified in situ technology. It has a 1986 production target of 57,000 barrels of shale oil per day. Other developers of Colorado shale include Exxon USA and Tosco (46,000 barrels per day), Union Oil of California (9,000 barrels per day) and Multi Mineral Corporation, which is extracting secondary shale oil and alumina in a nahcolite mining operation.

Less ambitious, but potentially significant because of its low capital costs, is an in situ demonstration in Utah by Geokinetics Corporation. The Geokinetics horizontal process requires a capital investment of only about $18 million for an operation with a 2,000 barrels per day capacity.

While the total private expenditures for oil shale have not been tabulated, the amount is obviously in the tens of millions of dollars annually and rising rapidly. An example gives a sense of the financial scale involved. In 1974, nine companies put up almost $450 million for leases to pioneer commercial oil shale development on federal land.

Government Activities

The U.S. government has spent about $150 million in research and development on several technologies to help develop a commercial-scale oil shale facility that is technically and economically feasible. The government plays a major role in oil shale development, partly because it owns 80 percent of the western oil shale lands. Moreover, private land cannot be developed without federal cooperation because government permits are needed to build roads, pipelines and transmission corridors across federal land.

Several agencies -- principally the departments of Energy, Interior and Defense -- are taking part in these development activities. The Department of Energy is funding three experimental oil shale projects to develop in situ processing technologies. It allocated $28 million for oil shale research in 1980 and another $36 million in 1981. Most of its work is on in situ technologies, although $15 million has been devoted to a two-year project on surface retort design.

The Department of the Interior has been active in oil shale development for decades. Currently, it leases four 2,100 hectare tracts, two each in Colorado and Utah, to private industry. Development has been underway on the two Colorado tracts since 1974, and the leases are expected to be renegotiated and extended to new tracts in 1981. In Utah, litigation has held up the development of the federally leased tracts.

The Department of Defense also has participated in oil shale programs; the Navy funded a project in Colorado that has produced about 100,000 barrels of shale oil. The oil has been refined and upgraded to produce five different fuels, including motor gasoline and various grades of diesel and aviation fuels. The Department of Defense has successfully tested these shale-based fuels extensively in ships and planes.

Future oil shale development will be supported by financial assistance provided through the U.S. Synthetic Fuels Corporation, a quasi-governmental corporation created by Congress in 1980.

Projections

Projections range between production of 250,000 to 500,000 barrels of shale oil per day by 1987 and 1 million to 2 million barrels per day by 1992.

TAR SANDS

In the United States, substantial deposits of tar sands have been identified at about 550 locations in 22 states. U.S. deposits (primarily in California, Utah, Kentucky, New York, New Mexico and Texas) are estimated to contain more than 36 billion barrels of oil. Utah deposits alone contain some 27 billion barrels of oil, of which 4 billion to 5 billion barrels are believed recoverable. The Utah sands yield about 40 kilograms of bitumen per metric ton of bitumen-impregnated sands. While Utah tar sands deposits contain adequate resources to support a tar sands oil industry, they are not ideally suited for exploitation with current technologies. Most of Utah's deposits will require in situ recovery technologies.

Internationally, Canadian tar sands operations, yielding more than 120,000 barrels of oil per day, are the world's largest. Venezuela, Romania, the Soviet Union, Albania, Madagascar and Trinidad also have significant tar sands deposits.

Tar sands bitumen can be recovered by either in situ or surface mining techniques. The most promising in situ techniques are steam drive and in situ combustion. Steam drive involves injecting steam into the formation to heat the oil, reducing its viscosity and pushing it toward production wells. In situ combustion involves injecting air into the formation to maintain combustion. The resultant hot gases vaporize the lighter bitumen components and carry them to production wells. The coke deposit which is left behind serves as fuel for the advancing flame front.

Many techniques have been prepared for extracting the bitumen from mined tar sand ore. The three most promising are a modification of the Canadian hot water process, the use of solvents to displace the bitumen and retorting. Surface mining is feasible in the United States for the 10 to 20 percent of all U.S. tar sands which do not lie deep underground.

Applications and Status

Synthetic crude oil obtained from extracting and upgrading bitumen can be used much like conventional crude oil -- it can be refined into gasoline, jet fuels and other petroleum products. Almost all efforts to extract energy from tar sands have been experimental, and most have been conducted by oil companies with at least some federal funding. Some deposits have been exploited to obtain paving materials, and the less sandy tars have been converted into chemicals. In the mid-1970s, some Utah tar sands were processed in experimental plants, but no commercial operations have been established yet.

Developing U.S. tar sands will take time. In Utah, the existence of conventional oil and gas resources removes the urgency for extracting hydrocarbons from the state's large deposits of tar sands. Moreover, the nation's massive reserves of oil shale and coal dwarf tar sands resource. Then too, the Canadian experience shows that it can take a decade to solve the technological and environmental problems associated with large-scale tar sands development. The U.S. activities, of course, will be speeded up because of the earlier Canadian development.

Economics

Unit production costs for fuels from tar sands are beginning to become available. However, they depend upon the type of deposit and recovery process used. Nonetheless, Canada's success in mining tar sands has given a boost to U.S. efforts, raising the expectation that development of tar sands will eventually be cost-competitive with the production of other synthetic fuels.

Private Activities

Industry interest is primarily focused on finding effective extraction and processing methods (especially for surface mining) and on patenting promising techniques. The capital provided by new government programs is expected to stimulate increased activity. A significant portion of the U.S. tar sands activity is directed by small companies.

Government Activities

The Department of the Interior plans to lease Utah tar sands tracts to private industry in 1981. Details of the leasing program have yet to be announced, but environmental impact statements are being prepared for five areas, two of which will be leased.

The Department of Energy's tar sands program budget totals $12.7 million for the fiscal years 1979, 1980 and 1981. The main thrust of the program is to develop in situ recovery techniques that can be applied to the 80 percent of the U.S. resource that is too deep to surface mine. To date, three field tests have been conducted. Additionally, financial assistance is expected to become available through the U.S. Synthetic Fuels Corporation.

Projections

Commercial production goals for tar sands have been modest, because little experience has been accumulated with the technology and the development of other energy sources is receiving higher priority. A tar sands operation in the United States capable of producing 80,000 to 120,000 barrels per day is possible by 1990.

West Germany

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INTRODUCTION

In the Federal Republic of Germany, new and renewable sources of energy have been explored and utilized by means of technological development for several years. They are among the priorities of the federal government's energy program (other priorities being energy conservation, advanced coal technologies and the limited development of nuclear energy), and their purpose is to reduce the dependence on oil.

Owing to the Federal Republic's topography, geography and climate, and because of its highly industrialized infrastructure and density of population as well as the mostly centralized organization of energy supply, the new and renewable sources of energy have individually varying potentials concerning their future contribution to energy supplies. Although their useful potential is, in the long term, not to be neglected, it will not be large in comparison with that of other primary sources of energy.

WATER POWER

Potential

In the Federal Republic of Germany, approximately 90 percent of the economically useful water power potential is used for electricity generation. The annual output of energy produced by water power stations amounts to 18.7 TWh, with a total installed capacity of approximately 4 GW. For 1980, the share of water power in the overall electricity generation in the Federal Republic of Germany amounts to approximately 4 percent. (At present, therefore, the installed pump storage output available to meet peak load demand amounts to about 5,000 MW, or 6 percent of the total installed electric capacity.)

Because of the Federal Republic's topography and population density, the further extension of river water power stations, pump storage power stations or conventional storage power stations is narrowly limited.

Present Level of Technology and Development Trends

Water power utilization is sophisticated and technically fully developed so that radically new developments are not expected. Advanced engineering methods developed in the Federal Republic make it possible today to comprehensively analyze the hydrological supply. Depending on local conditions, various proven turbine designs are used to achieve optimal conversion of the energy contained in running or dammed water to mechanical rotation energy. Such turbines are manufactured in all power ranges and designs in the Federal Republic of Germany, and they are used all over the world.

Particular mention should be made of water power stations in the range of several kilowatts to 1 MW for heights of fall from 1 meter to 200 meters. The turbines for such small water power stations are fully developed, regarding reliability, their minimal maintenance needs and their simple design. Early this century a large number of these plants formed the basis for electrification in Germany. During many years of use they have proved their worth all over the world under the most varied conditions.

The structural parts, such as dams, locks and supply tunnels, can be constructed with the aid of advanced and variously proven building technologies. Here, too, the Federal Republic of Germany can look back on extensive construction experience.

Cost

The cost structure of water power stations is specific in that the prime cost is high and the operating expenses are low, compared with thermal power stations.

In the case of river water power stations, the construction cost accounts for about 60 percent, while the remaining 40 percent is for electro-mechanical components. In the case of storage power stations, construction costs amount to approximately 80 percent, while 20 percent is for machinery. The power-related plant costs of large-scale water power stations are estimated to amount to DM 2,700 per kilowatt to DM 4,000 per kilowatt, depending on the site and the type of plant. Specific energy production costs are dependent on the utilization rate of the plant. For peak-load power stations with 2,000 operating hours per annum the energy production costs range between DM .15 and DM .21 per kilowatt; for base-load power stations with storage and with 7,000 hours of operation these costs can be brought down to between DM .041 and DM .061 per kilowatt.

Aspects of Utilization and Problems

In water power stations without storage the energy must be used as it is produced in accordance with seasonal variations. Large-scale facilities therefore, are, preferably operated as base-load power stations in connection with the electricity grid. However, to have a sufficient power output in times of reduced water discharge, additional thermal power must be made available. Power stations with storage can make it possible to compensate for supply fluctuations, and the time at which the electrical energy is called off can largely be chosen freely. For this reason power stations with storage are used as peak-load power stations, as well as for back-up and regulatory purposes.

Small-scale decentralized, usually river-based, power stations which supply industrial firms require a relatively steady supply of water throughout the year.

In addition to the construction of dams for water power stations, structural measures taken at the same time could be significant -- for example, extension of irrigation agriculture, improvement of navigability, establishment of a fishing industry or a lessening of flood hazards.

In contrast to electricity generating water power stations, pump storage power stations are used solely for the purpose of storing electrical energy. If there is a surplus of electrical energy, water from a lower reservoir is pumped to an upper storage reservoir by means of a power-driven pump. At times of demand for electrical energy the upper reservoir is discharged again.

In the Federal Republic of Germany there are various water management acts which must be observed in the planning of water power stations. As a rule, the restrictive provisions contained in these acts refer to the admissible distribution of water volumes and water levels in terms of space and time.

Adverse effects on the environment are an essential aspect which was, however, little heeded in the past. Hydrological changes occurring in the wake of water power utilization and the resultant effects must be studied at an early stage of planning if damage to the environment, agriculture or the natural water balance is to be avoided.

For many countries it will be important to increasingly identify and utilize water power resources in addition to fossil sources of energy, because water power stations are particularly economical, simple and robust and because their operating and maintenance requirements are small in comparison to fossil energy technologies.

It can, for example, be assumed that only 2 to 3 percent of the water power potential of Africa is being used for electricity generation. In Asia, this share is probably 12 percent, and in South America about 6 percent.

The federal government is promoting a large number of dam-building and hydro power projects. Examples within the framework of financial cooperation are water power stations in Turkey, Morocco, Tunisia, Nepal, Thailand, Sri Lanka, Burma, Kenya, Malawi, Mali, Senegal, Burundi, Tanzania, Brazil, Honduras and Peru. In the field of technical cooperation, energy planning projects worth mentioning are under way in Guatemala, Colombia, Peru, Argentina, Malaysia and Indonesia. Under these projects, hydro power is to be given greater priority. In the framework of this technical cooperation, the federal government makes available existing know-how for the preparation of energy and water master plans to interested developing countries. A number of master plans have been drawn up, or are being drawn up with support from the federal government. Other plans are in preparation.

In addition, large-scale projects for water power utilization are carried out on the basis of private industrial cooperation.

Solar Energy Potential in the Federal Republic of Germany

With a median sunshine duration of 1,600 hours per year, the average annual intensity of global radiation upon the area of the Federal Republic of Germany is 10^3 KWh per square meter. The most important constraints governing the technical utilization of solar energy in the Federal Republic of Germany are:

- The low power density in this country (with direct solar radiation at maximum 900 watts per square meter and annual average approximately 110 watts per square meter); this relatively low value calls for the development of efficient technologies, such as high-efficiency collectors and storage systems.

- The fluctuations in solar energy availability, depending on the time of day, the weather and the season, with the daily and seasonal solar radiation curve being exactly opposite to that of heating requirements.

For these reasons, research and development in the field of solar energy is closely related to other areas of general energy technology, including thermal insulation and heat recovery systems.

Projections for the year 2000 indicate that in the Federal Republic of Germany the contribution of solar energy to the overall primary energy supply through direct utilization via low-temperature collectors and through indirect utilization via heat pumps could amount to about 5 to 6 percent.

State of the Art in Solar Technology and Development Tendencies

In recent years, the development of components and investigation into solar systems has been supported strongly through government measures.

Today, different types of flat plate solar collectors are manufactured in the Federal Republic of Germany on an industrial scale. Flat plate solar collectors with an overall surface of about 33,000 square meters were manufactured between 1974 and the end of June 1978. In the last six months of 1978 alone, after the initiation of the DM 4,350 m energy conservation program of the federal and the Lander governments, 17,000 square meters were produced. In 1979, production rose to approximately 53,000 square meters, and in 1980 West German industry produced more than 100,000 square meters of flat plate solar collector area.

Unlike simple designs, including low-cost plastic collectors without any additional covers, more efficient solar collectors normally have selective absorber layers and up to two glass covers. A number of high-efficiency special designs also are being manufactured, such as heat pipe collectors or evacuated collectors with additional reflectors, but also air collectors (particularly for agricultural applications). Industrial processes have been developed to produce collectors at the lowest possible cost.

The specific cost for solar concentrator systems presently amounts to about DM

1,200 to DM 1,400 per square meter, while the prices for systems with low-cost flat plate collectors are in the range of DM 80 to DM 250 per square meter. The cost for standard collectors is DM 250 to DM 500 per square meter, and for high-efficiency collectors DM 500 to DM 800 per square meter.

Water Heating Systems

In the Federal Republic of Germany, more than 30 different manufacturers produce water heating systems. By 1980, a total of about 10,000 solar systems had been installed, primarily for water heating in private households during the summer months. Systems of this type are being offered at prices from DM 7,000 to DM 11,000. Results obtained by a representative survey indicate that about 85 percent of the users are satisfied with their facilities, and in particular with their reliability and maintainability.

Parallel to a large number of government-funded research and development and demonstration projects, solar industry companies and crafts associations have taken the initiative to train craftsmen who install such facilities. Their aim is to provide reliable after-sales services, which are a decisive prerequisite for the broader commercialization of solar technology in the domestic market.

An interesting application of solar systems, even under the less favorable climatic conditions prevailing in the Federal Republic of Germany, is water heating for public and local institutions (in particular for sports facilities, such as public swimming pools, and for schools and hospitals).

In view of continuously rising operational costs, especially fuel oil costs, an increasing number of municipalities feel compelled to make use of all possibilities to reduce the current operational costs of these facilities. One such possibility is solar water heating in combination with measures to reduce heating requirements. In the Federal Republic of Germany there are about 2,750 public open-air swimming pools, of which 2,600 could be heated to intensify their utilization by a larger number of bathers and to prolong the swimming season. In addition, there are about 250,000 private open-air swimming pools with an overall surface larger than the surface of all public open-air swimming pools together.

A large, public open-air swimming pool in the Federal Republic of Germany was equipped with a combined flat plate type collector/heat pump heating system for research purposes. With a surface of 1,500 square meters, this facility ranks among the largest flat plate collector systems existing in this country.

Space Heating Systems with Heat Pumps

Space heating accounts for almost 40 percent of energy requirements. There is an increased trend in the Federal Republic of Germany, especially in view of the prevailing geographic and climatic conditions, toward indirect utilization of solar energy by means of electric heat pumps. These heat pumps extract the energy supplied by the sun and stored in ambient air, in the ground or in ground water or river water via appropriately designed heat exchangers, and raise it to a higher temperature level suited for space heating systems.

In the strongly expanding German market, about 30 different companies offer fully developed heat pump systems, especially vapor-compression heat pumps with a power range from 1 KW to about 30 KW for single-family houses, but also heat pumps driven by diesel or gas engines with an output of more than 50 KW for larger residential blocks, administrative and office buildings.

By 1980 approximately 50,000 heat pumps had been installed in the Federal Republic of Germany. This figure is expected to rise to more than 250,000 by 1985. In 1979 only about 15,000 systems were in operation. These figures clearly illustrate the greatly increasing importance of electric heat pumps which, however, require the availability of an appropriate power supply grid and infrastructure.

Depending on the coefficient of performance, the specific costs of such heat pumps are between DM 500 and DM 1,000 per kilowatt including installation cost. Compared to a conventional oil-fired heating system, about 30 to 35 percent of the energy cost can be saved in this way. This means that heat pump systems are today very close to the break-even point and will become more attractive as oil prices increase.

This data does not include smaller heat pumps driven by gas engines and absorption heat pumps which may be used in single-family houses and multiple dwellings. It does not appear unrealistic to expect these types of heat pumps to compete in the market with the electric heat pumps by 1985, in particular because under ongoing research and development projects the improvement of heat pumps driven by gas and diesel engines as well as the development of absorption heat pumps are being pursued with great intensity.

Larger heat pump systems driven by gas engines in the power range in excess of 50 KW are already in the market and are mainly used in administrative and business buildings, schools, hospitals and indoor swimming pools. In the Federal Republic of Germany there are about 3,000 systems of that type.

Long-term developments might lead to thermodynamic heating systems combined with large absorber roofs that hardly differ in appearance from conventional roofs, but in addition to weather protection assume the function of a heat exchanger to utilize ambient heat.

It appears quite possible that new technological developments (such as energy roofs, energy facades and energy fences combined with heat pumps and low-temperature space heating systems) could play a significant role, particularly in view of the geographical situation of the Federal Republic of Germany. It is quite obvious that during the summer months solar collectors will contribute to water heating both in the Federal Republic of Germany and in regions with more favorable climatic conditions, depending on the respective requirement profiles.

Solar Energy in Agriculture

In German agriculture, energy requirements more or less coincide with the growth or harvesting periods. Interest is focusing on the technical utilization of solar energy, such as for drying purposes and for domestic warm water supply in addition to the traditional use of this energy source. This prompts the idea of reducing fuel oil requirements of conventional grass or grain-drying facilities, especially with the aid of air collectors. A prototype system for a cooperative large-scale drying facility (collector surface 1,500 square meters) has been successfully operated for about two years.

In vegetable farming, the use of translucent plastic foils for harvest advancement and for the extension of the cultivation period in autumn has been a widespread practice for years.

Due to the climatic conditions prevailing in the Federal Republic of Germany, energy costs play a decisive part in greenhouse horticulture. It is the aim of broad-based research and development activities to optimize the plant-oriented thermal economy of these facilities by using solar energy. In addition to the greenhouse proper, novel heating and storage systems, including the utilization of waste heat from industrial heat sources, also enter into considerations.

WIND ENERGY

Under favorable conditions, for example along the northern German coast, wind energy measured at an altitude of 100 meters reaches an average annual power density of 700 watts per square meter and a specific annual power of 6,000 KWh per square meter. This is many times the density of solar radiation.

In non-coastal areas the influence of ground friction on the movement of air increases considerably so that in the interior of the country wind machines can be used effectively only in exposed stretches of mountainous and alpine regions.

The useful technical potential of wind energy, including any necessary restrictions, is under study.

Under the Solar Energy Technologies Program, the Federal Republic of Germany has engaged intensively in the development and testing of wind power stations during the past seven years. Such wind machines up to a rotor diameter size of 10 meters have been used worldwide for pumping. The requirements to be met by modern wind turbines are, however, determined by the trend toward machines with higher drive speeds (generators, pumps and compressors). Although the high-speed wind machines required already are sold, their technical reliability in continuous operation has not been proved sufficiently. For this reason, nine different wind energy systems sold in the Federal Republic of Germany in the range of 10 KW are operated and tested on the North Sea island of Pellworm. The project is to study and compare the reliability and maintenance requirements of small advanced wind energy systems in continuous operation. The technical and economic parameters required to assess wind energy utilization are to be determined, also. In addition, a large number of other research and development projects are underway to study the possibilities of storage, of heating with wind energy and of combining wind and solar plants.

In the medium power range, a 265 KW wind energy converter is under construction. The plant possesses a horizontal high-speed, two-wing rotor with a diameter of 52 meters.

A large wind power station, GROWIAN I, of 3 MWe is being established on the German North Sea coast. This wind power station is a horizontal axis machine with a two-blade rotor running under the lee and a diameter of 100 meters as well as a mast height of 100 meters. The powerhouse is mounted on a swivel-bearing at the top of the tower. Given favorable winds, an annual electrical power of 12 x 10^6 KWh can be generated -- the plant could supply 4,000 households with electrical energy. Because the rotor blades account for a substantial portion of the overall cost of the plant, research and development projects concentrate on the development and testing of a new type of integrated fiber rotor.

During the three-year trial operation, the operating behavior of GROWIAN I is to be tested. At the same time, the suitability of wind energy systems for industrial-scale electricity generation is to be proved.

Also, other new designs with a one-blade rotor for large wind energy systems in the 5 MW range and with a rotor diameter of 145 meters are being developed under the title of GROWIAN II.

Cost

For the current small-scale plants up to 20 KWe, the specific plant costs amount to between DM 2,000 KWe and DM 10,000 KWe, depending on the type and design of the plant. Because of the small amount of wind energy available close to the ground, the annual workload is lower than with large plants. It is estimated at approximately 1,200 to 2,500 annual full-load hours. Depending on the prime cost, the energy price varies between DM .4 and DM 1 per kilowatt-hour. Given a fuel price of 8. DM/l and investment costs of DM 5,000 KWe, a small, decentralized wind energy system, which drives a water pump, for example, is able to compete with a small diesel generator if situated in a favorable site.

For large plants of the GROWIAN I type the prime cost in the prototype stage must be estimated at DM 10,000 per kilowatt. On the basis of an exclusively economic assessment, the prime cost should not be more than DM 5,000 per kilowatt, given the present price of electricity.

Aspects of Utilization and Problems

Plants in the lower power range, between 1 KW and 10 KW, in particular when connected with a storage medium, are particularly suitable for the decentralized supply of individual users (electricity for heating, cooling, lighting and communication, or mechanical energy to drive water pumps). Potential users are to be found in rural regions with favorable wind conditions, for example isolated farmhouses, entire agricultural units, single-family houses, weekend houses, village communities and camping grounds.

Medium-size plants ranging to several hundred kilowatts are particularly suitable as community units, supplying a fairly small number of individual users. Large plants, 1 MW upwards, can either operate independently or feed the energy they generate into the supply networks.

The operation of wind energy converters presumably will not create any particular environmental problems. The extent to which plant noise will be a nuisance still must be studied.

The speed of the air current will be reduced by energy utilization. This effect will be found if the wind machines are rather closely spaced and it is likely to prevent potential soil erosion in coastal regions or on plains not covered by vegetation. Compared with solar plants, wind energy converters require relatively little space. Visual impairment of the landscape, at least by small and medium-size plants, is no more serious than that caused, for example, by pylons.

Wind energy is a worthwhile option for developing countries that have windy and spacious regions and need a decentralized supply of energy.

A prerequisite is that the plants be particularly robust and require little maintenance.

BIOMASS

In industrialized countries, the utilization of waste products alone is quite sizable. In the Federal Republic, for example, it is expected that there will be approximately 64 million tons of dry organic substance (straw, 23.5 million tons; animal excrement, 14 million tons; biomass, such as beet leaves and potato foiliage, 13 million tons; domestic refuse, 7 million tons) and 4.5 million tons of dried ligneous wastes. If these quantities were converted into energy, the hypothetical potential would be about 19 million tons of coal equivalent (Tce).

How much of this will be economically useful will depend on the further development of the technical facilities for utilizing these products.

In the Federal Republic of Germany, advanced wood and straw incineration plants from several kilowatts to several MW for small users in the sectors of industry, agriculture and private households are offered a number of manufacturers. The plants meet the requirements of optimal incineration in terms of the emissions admissible and the efficiency required. Loading is either by hand or automatic. If straw and wood is burnt locally (that is, if no appreciable transport costs occur), the energy cost per kilowatt-hour is lower than that of purely oil-fueled plants so that an increase in the utilization of these materials is to be expected in the future.

In addition to direct incineration, other major technologies for the conversion and utilization of biomass are anaerobic fermentation into biogas and ethanol as well as pyrolysis and gasification.

Biogas

About 40 advanced biogas facilities recently have been built in the Federal Republic of Germany. A number of German manufacturers offer biogas facilities, from about 20 large livestock units up to several hundred units, with different types of containers, heating system insulation, heat recovery, circulation systems and mechanical devices.

Generally speaking, the utilization of biogas makes sense only where fairly large quantities of organic waste can be used on the site, without high transport costs. In the Federal Republic of Germany, this applies to sewage treatment plants, farms, enterprises of the food processing industry and carcass disposal plants. Gas emissions, which otherwise would pollute the environment, frequently can be used to produce methane, and this helps to achieve economical operation at an earlier stage.

In the facilities presently operated on farms, the gas obtained is used mainly for heating, cooking and drying purposes. Advanced sewage treatment plants in the Federal Republic of Germany which make use of biogas can meet their own demand for heat and power.

In the biogas field, the Federal Republic of Germany can offer comprehensive know-how and practical experience, which is at present being extended in a number of projects.

The operation of biogas facilities is of special significance because, by using the resulting nitrogen-rich fertilizers, countries can reduce their dependence on capital-intensive mineral fertilizers.

Ethanol

A number of research and development projects for the production of ethanol from biomass have been executed in the Federal Republic of Germany. They include studies to assess the potential suitability of various plants such as turnips, potatoes, corn and cereals and other raw materials such as waste paper and straw. In addition, microbiological, economic and process engineering studies are being carried out to optimize production processes. The technical development concentrates on bio-reactor designs which ensure economical production even if the reactor is small; they also focus on the erection of pilot plants and training shops for developing countries. The cost of producing a liter of alcohol from plants grown in the Federal Republic of Germany at the production site is estimated to amount to between DM 1.60 and DM 2.40. In several developing countries, the cost situation is more favorable because high-yield plants, such as sugar cane, can be used as raw material. Present projects include one undertaken together with Brazil.

Pyrolysis and Gasification

In pyrolytic processes, or thermal anaerobic digestion, the main types of biomass used are wood, peat, straw, organic waste and refuse. Depending on the raw material and process used, the energy obtained takes the form of gas, liquid fuel or charcoal. In the Federal Republic of Germany, various pyrolytic processes are being developed; at the same time, a number of pilot plants are being operated, where development work has reached a stage at which the planning of commercial facilities could be started. In addition, there are a few instances where gasifiers which make use of wood are being tested for stationary applications in the Federal Republic of Germany and are being manufactured also for developing countries.

The utilization of biomass is likely to be given considerably higher priority than other renewable energy sources, because the relatively simple technologies required (combustion furnaces, gas generation facilities, alcohol fermentation equipment) offer a wide range of applications (production of heat, electricity and fuels) and make energy supplies secure without the need for additional back-up systems.

ENERGY SUPPLY IN RURAL AREAS

The supply of energy to the rural areas of developing countries is of the utmost importance. Even the availability of relatively small quantities of energy can bring about a considerable change in the health, employment, education and general situation of the population. Clean drinking water and energy for cooking are basic needs of rural communities. In addition, energy is absolutely necessary for irrigation, communication and information systems, processing of agricultural products and the operation of small repair shops and manufacturing facilities.

The type of energy made available should not be restricted to electricity and should be geared to the different types of final consumption. In each case the energy technology should be designed to make use of the locally available energy sources.

Decentralized energy supply systems at the local level must be a viable and logical solution.

This is the philosophy behind the concept of "solar villages." Appropriate projects have been designed in cooperation with several countries (including Egypt, the People's Republic of China, Indonesia and Mexico) to develop and test different facilities which make use of solar energy, wind power and biomass to meet the energy requirements of rural communities. This includes single-source facilities as well as facilities combining the use of various energy sources.

New and renewable energy sources are used for water desalination and treatment, for hot water generation, for cooling and drying food; biogas facilities supply cooking energy; communication and training equipment as well as irrigation pumps are being provided with electric power from photovoltaic generators.

The different designs and projects, which take into account the specific economic and social situation of the respective village, will serve to study the applicability of the different technologies, their economic constraints and their social implications. Only after completion of the test phase, when the practical experience gained in these cooperative projects is available, will it be possible to draw well-founded conclusions as to the future prospects for the application of these energy generation technologies in the rural areas of the countries concerned. Initial results from these projects will be available in about two years.

GEOTHERMAL ENERGY

The temperature of the earth's crust rises with an average gradient of about 30°C per 1,000 meters. This means that normally the temperatures required for power generation occur only at great depths. This is why capital cost is so high that, with the present state of the art, no economical use of geothermal energy for power generation is possible. Economical power generation requires geothermal anomalies with high temperatures caused by volcanic activity, underground magma chambers or water rising from deep aquifers."

In the Federal Republic of Germany, the existence of natural steam or high-temperature hot water deposits in near-surface strata, which would offer the financially and technically most favorable type of utilization, can be excluded. There are several small local low-enthalpy aquifers with water temperatures of up to 100°C in the southwest and north of the country, but they have not yet been commercially exploited for energy supply purposes.

The federal government supports a number of research and development projects under which extensive geophysical, mineralogical and geochemical investigations are carried out to obtain more detailed information on geothermal energy. Temperature fields are being determined, magma chambers explored, heat flux densities and the thermal conductivity of deep rocks are being measured. The exploration methods for this work are elaborated almost exclusively by universities and government-supported research institutions. German experts in this field can compete with their colleagues abroad.

In addition to these exploratory investigations, the federal government gives considerable financial support to pilot projects at three different sites with a thermal output of 10 MW each: first, the extraction of water of a temperature of about 100°C for space heating (at Buhl); second, a facility for the combined supply of heat, drinking and industrial water for a number of different consumers (Saulgau Project); and third, a low-temperature heating for existing heating systems (at Freiburg).

In addition to research and development activities aimed at tapping the earth's heat stored in hot water reservoirs, the federal government has invested considerable funds to participate in the development of the hot dry rock technology, which removes the heat from deep-lying hot dry rocks. Since this technology can be applied practically everywhere, it offers good prospects for exploiting a vast energy potential. Apart from a number of small-scale projects in the Federal Republic of Germany and extensive Frac investigations for creating underground heat-transfer surfaces, there also is considerable German participation in the Fenton Hill Project carried on in the United States. The field experiments carried out so far have shown that the application of this technology in the Federal Republic of Germany is promising. It is estimated, however, that one or two decades will be required to develop this technology for commercial use.

Hot water deposits with a low enthalpy can only be used for heating purposes and hot water supply. Moreover, such use is only viable if the well yields a steady flow of 10 to 30 liters of hot water per second and the heating capacity is about 10 MW, so that a competitive heating network can be set up for a certain minimum consumer density in a given area. To minimize corrosion and the precipitation of salts damaging the plant and in the interest of environmental protection, water with a low minerals content will be preferred. If the earth's heat is used by tapping hot water deposits or by means of the hot dry rock technology for heating purposes, the heat price would range from DM .04 to DM .06 per KWh. The cost of power generation, however, in a hot dry rock power station would range from an estimated DM .30 to DM .40 per KWh, if water is extracted from a 4,500 meter well at a temperature of 150°C and with an electrical output of about 15 MW.

The utilization of geothermal energy in the Federal Republic of Germany is yet in its initial phase. In the long run, it may play a minor role in the energy supply to certain areas. Present estimates indicate that the contribution of geothermal energy to meeting the total primary energy demand of the year 2000 is likely to fall short of 1 percent. The technological experience gained so far, however, can be broadened in cooperation with interested developing countries.

OIL SHALE

In comparison with other energy raw materials, the hydrocarbons contained in oil shale have, in the past, been used to a very small extent. Recently, however, in view of decreasing oil and natural gas reserves and as a result of the present development of the price of crude oil, oil shale has become an interesting subject in discussions of the energy supply and demand systems. Considerable financial and technological efforts are now being made in order to utilize this potential.

In the Federal Republic of Germany there are several oil shale deposits, in particular in the north (near Schandelah). The presently workable reserves are estimated at 110 million tons of oil shale (presently workable means that, for cost reasons, the only method applicable is open-cast mining). The quantity just mentioned is more than twice the amount of established oil reserves of the Federal Republic of Germany. Domestic oil shale will replace about 2 to 3 percent of the German mineral oil imports in the years to come.

In the past, in particular during the two world wars, Germany built several plants for the conversion of oil shale by means of pyrolysis. During the same period, initial experiments were made for underground conversion. At present, the quantity of oil shale processed in the Federal Republic of Germany is negligible. The only commercial plant in operation uses oil shale as an energy raw material, taking the resulting residues as additives for the production of cement. In recent years, an average annual amount of 320,000 tons of oil shale has been processed.

Research and development projects include mapping of deposits, geochemical, hydrogeological and soil investigations, feasibility studies and advanced mining technologies. Pilot plants are being set up and operated to process oil shale by means of advanced conversion techniques. The resulting liquid products can then be processed almost like crude oil. The development work aims at building and operating commercial plants. For this purpose, considerable capital investment is required.

The extraction of oil from oil shale has almost reached the break-even point. Provisional estimates of the total cost per ton of shale oil in the Federal Republic of Germany are currently in the same price range as crude oil traded in the world market. The conditions for shale oil would be more favorable if the resulting residues could, in addition, be used as raw materials. However, it must not be overlooked that the production cost for oil from oil shale is merely estimated and involves an element of uncertainty.

Oil shale is, without doubt, an interesting energy potential. Its commercial utilization, however, still meets with numerous technical and economic difficulties. Negative environmental effects of the mining of oil shale and its processing should be avoided by taking the appropriate technical precautions. This will involve additional investment and operational costs.

DOCUMENT NUMBERS FOR ORIGINAL U.N. REPORTS

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