UNITED
NATIONS

A

United Nations Conference
on New and Renewable Sources
of Energy

Nairobi, Kenya
10-21 August 1981

Distr.
GENERAL

A/CONF.100/NR/18 *
12 March 1981

ENGLISH ONLY

NATIONAL REPORT SUBMITTED BY

NORWAY **

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81-07068

THE ENERGY SITUATION IN NORWAY
PAST, PRESENT AND FUTURE

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PAST, PRESENT AND FUTURE

CHAPTER 1

THE ENERGY SITUATION IN NORWAY

(a) DEVELOPMENTS IN CONSUMPTION TO DATE

1. Norway is one of the industrialized countries having the most abundant supply of its own energy resources. From old times fuelwood was an important source of energy. But water power has also been in use throughout long ages to power simpler mechanical installations, such as grindstones, saw-mills etc. From the beginning of this century water power was harnessed for the production of electricity. This triggered off 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 last 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 Figure 1.

(b) HYDRO-POWER

The construction of hydro-electric 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 2.

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 East Norway. In the 1950s and 1960s regional grid associations were created in West Norway, in Trøndelag and in North 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.

Towards the end of the 1950s an ever more extensive system of exchange of power has been 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 post-war period has been linked to an increasingly efficient technology. During the period 1960-70 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 have risen 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, are still 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 developments 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 50-60 years.

The exploitation of our low-cost water power resources has i.a. 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 has also 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 encroachments on nature and their 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.

As per January 1980 hydro-power cost about 12 øre per kWh ex powerplant, while oil-fired power is estimated at 23 øre per kWh and coal-fired power at about 16.5 øre per kWh. 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 16-17 million tons per annum, that is to say 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.

(c) 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 25.0 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 Figure 3.

(d) COAL AND COKE

Today coal and coke constitute a relatively modest proportion of Norwegian energy consumption. However, at the turn of the century over 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 last few years imports have been about 0.5 million tons per annum. At the same time a certain export has taken place, especially to West Germany for fuelling thermal power plants.

(e) 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 fuelwood. Today, the consumption of fuelwood is approximately 0.5 million cu.m, corresponding to approximately 4.3 PJ, or about 0.6 percent of the primary total consumption. The sharp decline which has taken place is due partly to the fact that, particularly in the cities, fuelwood 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 so-called Wood Chips Council which was actively engaged in promoting the use of wood chips as a fuel during the period 1959-62.

Apart from room heating, forest energy has in times past been of great importance in mining operations, wood-processing and smelting industries. The smelting industry used more than 100 000 tons of fuelwood in 1977 as a reduction material in the production of ferro-silicium. Of late the saw-mill 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 over a 1000 years, particularly in the non-wooded coastal areas of West Norway, in Trøndelag and in North Norway. Annual production has now declined to an estimated 2000 cu.m, 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.

CHAPTER 2

ORGANIZING AND FINANCING THE SUPPLY OF ENERGY

(a) THE TERMS OF REFERENCE AND RESPONSIBILITIES OF GOVERNMENT DEPARTMENTS

Energy questions affect many sectors of the community and the government administration. As a result most of the other Government Departments are also 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 Ministries affected 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 programmes 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 in order to reinforce the policy on energy. In addition the Ministry is responsible for such policy instruments as are 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 Programme 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, off-shore installations etc, energy consumption and industrial exploitation of the Norwegian petroleum deposits.

The Ministry of Local Government and Labour is i.a. 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 and the consequences of energy production and consumption which are important 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 also 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 fuelwood for energy purposes. Various research projects are underway in this field. The Ministry has at its disposal appropriations for supports to the felling of deciduous trees and for supports to 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 UN.

In addition, several other Government Departments are responsible for various aspects of energy management.

(b) THE NORWEGIAN WATER RESOURCES AND ELECTRICITY BOARD'S ROLE AND ORGANIZATIONAL STRUCTURE

(i) Historical survey and organizational 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.

(ii) The NVE's duties

Within the Electricity Administration, the NVE assists the Ministry with i.a. 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 i.a. 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, watercourse 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.

(c) THE RESPONSIBILITIES OF THE STATE, THE COUNTIES AND MUNICIPALITIES IN THE PRODUCTION AND DISTRIBUTION OF ENERGY

(i) The organization of the electric power supply services

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 less 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 greatly varying production conditions in respect of 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.

(ii) Local energy planning

Most of the production, transmission and distribution of electricity is conducted under public auspices with the State Power System as 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 are also showing an increased interest in district heating production and district heating supplies based on for example forestry waste, industrial and household waste, as well as 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, 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 as well as 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 programme 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. In order 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 programme of action may be prepared, where a study is submitted on how the consumption cf energy can be covered in future. As regards the larger cities, it might for example be appropriate to work out thermal schemes. As regards 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.

(d) 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 own capital resources. Figure 4 shows how the supply of electric power has been financed during the years 1972-79.

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, i.a. by district heating based on local energy resources, such as wood-chips, bark, waste heat etc. or heat pumps, energy recovery plants etc. on a larger scale. Larger thermal power plants will hereafter be sought 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 1976-79 approximately Nkr 145 million was granted in loans and about Nkr 120 million as loan guarantees, totalling approximately Nkr 265 million. Total investments in such measures are calculated at approximately Nkr 415 million.

CHAPTER 3

RENEWABLE SOURCES OF ENERGY - RESOURCES, TECHNICAL POSSIBILITIES AND ENVIRONMENTAL CONSEQUENCES

(a) LIMITATIONS IN THE USE OF 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 10-15 percent of our total gross energy production towards the end of the 1980s.

Since 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 the biomass in addition to hydro-power. Section (b) of this Chapter contains an assessment of these sources of energy.

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, 5-10 years, other sources of energy such as wave-power, bio-energy, solar heating and wind-power in Norway are hardly likely to to be able to compete in terms of cost with today's sources of energy. But in the longer term the situation may change in respect of 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. One example might be a conflict over use between on the one hand fishery and shipping interests and on the other wave-power, or rival claims for land as between agriculture and forestry.

All readjustments of energy systems take time. Decisions taken today will have effects in 10-30 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, environmental considerations etc.

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 around the end of this century.

(b) RESOURCES AND TECHNICAL POSSIBILITIES

(i) Bio energy

Norway's annual yield of timber, i.e. trunks with bark, is about 18 million cu.m. Of this about 12 million cu.m is used in production and the surplus is therefore about 6 million cu.m If we include branches, tops and roots, the yield can be estimated at 25-30 million cu.m annually. The <u>theoretical</u> energy content in the total yield amounts roughly speaking 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 proportion 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 so-called marginal timber reserves such as tree-stumps, felling waste, thinnings etc.

Utilized for energy purposes, the biomass can be burned direct or transformed into liquid fuel or gas. For the time being the solid forms, such as fuelwood, 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 one 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, i.e. close to three 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 cu.m for timber used in production can be increased in the longer term to about 15 million cu.m even with traditional forestry techniques.

How far biomass in future will be competitive in relation to 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, fuelwood, according to estimates made in 1978, would cost in round figures 10 øre/kWh. Cord wood delivered to the consumer is dearer, however, and would give energy prices in the region of 20-40 øre/kWh. In the case of transformation into charcoal the costs were estimated to be 15-30 øre/kWh, 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 cu.m of raw peat. The annual yield is estimated to be about 5 million cu.m 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 would also require a relatively large amount of energy to utilize them. It is therefore only feasible to make practical use of some of these.

(ii) Wave energy

The total energy content of the ocean waves that roll in annually towards 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 metre wave-crest outside the skerries. Only a fraction of the theoretical energy content, however, will be utilizable in practice.

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 to the hydro-power system.

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

It is for the present 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 20-100 øre/kWh. The most comprehensive cost estimate so far has been carried out for the buoy project and suggests costs down to 20-30 øre/kWh. 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 out from two different 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 Kværner 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 focussed.

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. Figure 5 shows how a wave-power plant of this type can be envisaged. 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 m and normal wave conditions provide for an optimum distance between the buoys of 50-100 m. According to the calculations worked out, a wave-power plant which is to produce 1 TWh/year net will consist of about 1000 buoys and require an area of 5-20 sq. km.

Instead of an oscillating buoy, wave energy can be transferred 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 as light can be focussed with the aid of a burning-glass, ocean waves can be focussed 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 30-50 m below the surface of the sea. The ocean waves can then be gathered in towards a focussing point where the waves can be over ten times greater than the swell reaching the lens.

At the focussing point a funnel-shaped chute, for example, is envisaged leading the waves up into a high basin. The potential energy the water has in the basin can then be used as in an ordinary hydro-power plant. An outline sketch of the focussing power plant is shown in Figure 6. Other possible ways of transforming wave energy into electricity are also being considered. The lens elements could be placed in a 10 km long row. With the basin placed to give a 50 m drop, a plant of this nature could in theory provide up to 0.7 TWh electricity production per year.

These projects are now proceeding with support from public funds, approximately Nkr 33 million having been used 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 course of the 1990s.

(iii) Solar energy

Around 60 degrees latitude the mean solar radiation is 100 W/sq. m on a horizontal plane so that the annual mean for the solar energy is about 900 kWh/sq. m. Of this, just under 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 2-3 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. Today 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 through 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 levelling out over a period of 1-2 weeks, solar heating can cover 30-50 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 are already marketing solar-heated houses. Today housing is being renewed at a rate of 35 000-40 000 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 that 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 not inconsiderable proportion of the total housing with solar energy. The increase in energy prices will naturally be able to make solar heating a profitable proposition also for existing housing.

Given the above 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 floorspace per housing unit and altered patterns of energy consumption otherwise. 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 around 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 30-60 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 15-25 PJ.

With today's technical solutions, the cost of heating in a Nordic climate is about 30-50 øre/kWh of thermal energy. The cheapest solution appears to be larger solar heating systems for group housing or larger buildings etc. The cost of energy will naturally also depend on the depreciation time and calculated interest, so that it is seldom possible, directly to compare the different price estimates. At present the cost of solar energy in Norway is 2-3 times higher than heating from conventional sources of energy.

(iv) 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 windspeed at a height of 10 metres above ground-level is about 7 m/sec, which corresponds to a theoretically usable effect of 0.13 kW per square metre vertically to the direction of the wind. Inland there is too little wind energy for practical purposes. Since the wind energy varies greatly in the course of the year, to make any extensive use of it would require its being coupled to 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 can therefore only be estimated with a large measure of uncertainty. Various estimates suggest a <u>theoretical</u> energy potential in the region of 200-600 TWh per year for the belt between 50 and 150 m above groundlevel. Only a small amount of this can be used in practice.

A <u>wind-power plant</u> may consist of an array of wind turbines. A power plant with for example 12 wind turbines about 100 m high, each of 4 MW maximum rated power, may be assumed capable of supplying about 0.1 TWh electric energy per year. With the building of 1-4 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 3-12 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 sq. km and restricts the use of the area for other purposes.

The cost of energy is very dependent upon the size of the power unit and oh the wind conditions. For small windmills, under 40 kW, such as are available on the market today, the cost of production is in the region of 30-50 øre/kWh in places with average wind speeds of 5-6 m/sec. For power units in the MW-class the energy cost is estimated at 10-30 øre/kWh. 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 further away from consumers.

(c) OVERALL ASSESSMENT

Figure 7 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 around the turn of the century seem to indicate that it will be necessary to have an energy production in the region of 1000 PJ or about 23-24 million tons of oil equivalents. If we allow for a gradually more effective use of energy, for example, perhaps a gross energy production of 1000 PJ would also 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 10-25 percent to energy supplies round 2020. Including hydro-power, the share of renewable energy sources according to this illustration would even so only amount to half of the energy production and there will therefore continue to be serious pressure on the finite stock resources coal, oil, gas and uranium.

Other energy sources than those which have been mentioned such as geothermal energy, temperature differences in sea water, tidal differences etc 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. As regards 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 levelling 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 up against other public tasks. The authorities will also 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' 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 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 10-15 percent of Norway's energy supplies, or 100-250 PJ, from bio-energy, and wave, solar and wind energy.

(d) ENVIRONMENTAL CONSEQUENCES CONNECTED WITH THE PRODUCTION AND CONSUMPTION OF ENERGY

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

It is often difficult to weigh up the desire for the benefit dependent upon an increased supply of energy as 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 addition there is the fact that 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.

(i) 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 therefore 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 made in the natural course of the watercourses 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 powerlines.

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, in the groundwater level, and river-bank 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
- Fishing and hunting
- Preservation of cultural monuments
- Local environment
- The conditions in maritime and lake districts
- Water supply and drainage
- Agriculture and reindeer husbandry
- Timber floating and other forms of transport
- Tourism

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, than previously. It is also more often the case that a government concession is not granted or that parts of a watercourse that are specially 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. In order 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 so as to make allowances for a rapid filling up of the reservoirs when winter is over and for fish conservation, icing, water requirements, scenery, etc. 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 then 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 such as agriculture, water supply, etc.

The Government intends to develop the remaining hydro-electric 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.

(ii) Other renewable sources of energy

Direct exploitation of the 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 CO_2 will cause no problems, since the intake of CO_2 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 0.1 and 1 sq. km per GWh 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 sulphur 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 will probably 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.

The transformation of the 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 can conceivably be built in accordance with various principles, and the environmental effects will be to some extent dependent on which technical solution is adopted. All wave-power stations are intended to extract energy from the ocean waves, and this entails an average reduction of the wave-height on the leeside of the wave-power station as compared with its original state. The focussing type of wave-power station will concentrate the wave-height in towards a point on shore, but reduce the waves on both sides of this point. On the windward side of the wave-power station too the waves may be altered, since some of the waves are reflected, so that 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 focussing power station will require a safety zone around the point where the waves are collected. Generally, safety zones for wave-power stations will be equivalent to 5-20 decares per GWh 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 windturbines it is necessary to have safety zones of several hundred metres in order to reduce the risk from a fracture of the rotators or icing on the vanes. This ground can nevertheless be used for agriculture etc. It can be of practical interest to build windturbines with an annual production of from 0.1 GWh to 30 GWh. The space required per GWh of annual production will be approximately 5 decares for the building site and 200 decares for safety zones for the largest windturbines. The large windturbines will dominate the landscape, and it would be better to site them along the coast or out at sea.

If the windturbines are situated in previously untouched natural surroundings, the construction of approach roads and powerlines 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 will hardly be of any considerable significance. Large windturbines, especially with metal vanes, may cause disturbances in aircraft telecommunications and should therefore not be situated under or near to flight corridors. Radio-based communication systems may also be disturbed. It can be assumed that such windturbines 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 windturbines along the coast. Outside the safety zones that will presumably be established, radio or TV disturbances are hardly likely.

The space required for the use of solar energy for heating will be of small significance, since solar panels will usually 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 thus 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 m for the storage tanks, this will amount to 2 decares per GWh 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 GWh will require 10-20 decares of solar cells. Solar cells for electricity production can also be combined with thermal catchment and will then require less space per GWh than the electricity production alone.

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

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

(iii) 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 treeline the choice of route and the right type of mast can, nevertheless, 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 may also block the migratory paths of the deer family, at any rate temporarily. 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 up in the process of planning and negotiating government concessions for power-lines. In the course of construction, cross-country vehicles are often 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 it may take several decades to repair. The use of helicopter transport can reduce such damage.

(iv) 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 will also 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 centres 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 will also 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 with regard to both what we use the energy for and how the energy supply is organized.

CHAPTER 4

FUTURE DEVELOPMENT OF CONSUMPTION AND ENERGY COVERAGE

(a) ENERGY UTILIZATION

(i) General consumption

In spite of existing uncertainties, we must make certain estimates of the demand for energy in the years ahead, so that we shall have a basis for planning energy supply and, in the event, take other measures in order to influence the energy balance in future. At the same time these circumstances stress the need to keep a running assessment of both energy forecasts and the effects of measures carried out.

The forecasts may be regarded as an estimate of the supply of energy considered necessary for maintaining a certain level of economic growth in Norway. Given the importance the Norwegian authorities attach to safeguarding full employment and to strengthening industrial development, this means that planning should aim at ensuring that the supply of energy must be able to support a reasonable rate of economic growth. But energy supply will not of itself be sufficient to achieve the desired economic development. If the other premises for growth are fulfilled, the energy supply will provide the basis for such growth. Figure 8 shows the expected development in energy consumption in the general consumer sectors and the ceiling set for electricity used in power-intensive industries. The Figure shows that the annual consumption of electricity in general consumer sectors increases from slightly over 46TWh, according to the energy accounts in 1977, to about 70 TWh in 1990. This corresponds to an annual percentage increase of overall 3.2 percent annually on average up to 1990. Oil consumption in the general sectors is estimated at 9.0 million tons in 1990, as against 7.3 million tons in 1977.

(ii) Power-intensive industry

This industry today disposes over approximately 30 TWh gross on an annual basis. For 1985 the Norwegian authorities have set a ceiling of 31 TWh gross. On the basis of an overall assessment the firm-power ceiling for power-intensive industry has been set at 34 TWh gross for 1990. The ceiling includes both power from the industry's own power plants as well as purchased power. The limitation inherent in such a ceiling acts at the same time as a stimulus to the industry to make better use of the total amount of power available to it.

(iii) Total energy

The sum of the firm-power potential for the 70 or so operational units has been calculated in 1979 to be about 80 TWh per year. The overall estimate for 1985 amounts to 94 TWh gross firm power. Of the electricity consumption, general consumption equals 59 TWh and the firm-power ceiling for power-intensive industry 31 TWh. In addition an extra amount of 4 TWh is allowed for covering uncertain factors.

On the basis of an overall assessment the Norwegian authorities have set a consumption ceiling of 106 TWh gross for firm power in 1990. This will cover a general consumption of 70 TWh which accords with the basic alternative, a firm-power ceiling of 34 TWh for power-intensive industry and a reserve of 2 TWh for, among other things, the uncertainty in the consumption estimates.

Figure 8 shows estimates of oil consumption for the general consumer sector. In addition, purely on the basis for assessment, the power-intensive industry's oil consumption has been estimated at 1.3 and 1.8 million tons of oil for 1985 and 1990. These figures also include the oil used as raw material in the petrochemical industry.

No separate prognosis calculations have been made of the consumption of solid fuel (coal and coke) in future years. In 1977 it amounted to about 1.3 million tons and was primarily related to power-intensive industries. For 1985 and 1990, at a very rough estimate, the consumption of solid fuel is calculated to be respectively 2 and 2.5 million tons. No provision has been made for the operation of coal-fired power plants in this period.

(b) COVERAGE OF DOMESTIC ENERGY UTILIZATION

(i) Organization of electricity production system

In view of the energy resources which are expected to be able to contribute to our electricity supplies in the 1980s, it is the opinion of the Norwegian authorities that the bulk of these must come from water power. This view is also based on the fact that hydro-power has advantages in terms of cost as compared with thermal power, an advantage which it must be assumed will increase in the future with the expected development of oil and coal prices. As regards environmental considerations too, hydro-power seems the most favourable, in that in planning the hydro-power projects great emphasis is placed on limiting encroachments on the natural environment, at the same time as showing due consideration for other and competitive user interests in connection with the watercourses. Hydro-power also has obvious environmental advantages as compared with electricity production based on oil and coal. The same applies in the consumer sector, if the alternative is direct firing with coal or oil. Hydro-power also constitutes a stable and reliable renewable source of energy, not dependent upon the international energy situation. To the extent that we find it compatible with due regard for nature and the natural environment, in using our hydro-power resources there will be correspondingly less exploitation of our non-renewable energy resources. This is especially important in regard to oil which is now becoming a scarcity factor in world supplies of energy.

Transmission losses today for general electricity consumption are about 16 percent. A reduction of the losses to around 12 percent will probably prove to be economically profitable with energy prices which reflect the costs for new power. Such a low loss percentage is hardly likely to be the case before the turn of the century.

In power-intensive industries and wood processing, the installation of <u>back-pressure power units</u> and thermal power plants for the <u>exploitation of waste heat</u> could make a certain contribution. Studies of power stations based on a combination of waste heat exploitation and coal-firing should continue with a view to better clarification of the practical possibilities, economics, technical solutions, environmental effects etc. The Ministry of Petroleum and Energy will make running assessments of the technical, economic resources and environmental aspects of power production from possible gas-fired power stations on platforms in the North Sea or power stations based on shore-delivered gas.

In view of the limitations we will face in regard to further hydro-power development in the 1990s, the right course would be to continue with the planning of a thermal power station which if necessary can begin to operate early in the 1990s. At the same time technical, economic and environmental studies ought to be made of somewhat smaller thermal power stations and of combined electricity and district heating plants.

On the basis of present prognoses and available energy resources it does not seem necessary today, in order to meet energy needs, to make use of nuclear power in our energy supply system before we reach the turn of the century.

Electricity production from other sources such as wind, waves, sun and biomass has come no further than the research stage. Only relatively rough estimates can be given at present for possible future contributions from such sources up to the year 2000.

Figure 9 shows a basic alternative for power coverage in the 1980s. The figures for the years up to and including 1985 are in all main respects related to plants already in operation or under construction. To cover the consumption allowed for in the basic alternative, there is however a need for further supplies of 3 TWh firm power. In the period in question this extra amount can only be derived from hydro-power stations, preferably from projects where planning and the question of government concession are already in hand.

The total firm-power potential for exploitable hydro-power today is estimated to be about 150 TWh or 170 TWh average production. Small hydro-power sources and re-equipping of older power stations are then included in these calculations. Of this 150 TWh, projects with a firm-power potential of 89 TWh have already been constructed or are under construction. If we take the proposal for the protection of watercourses into account, a total firm-power potential of about 20 TWh will be permanently or temporarily protected.

With the present great uncertainty as to energy needs and acceptable alternative energy sources in the long term, it is very difficult to suggest where the ceiling should be set for future hydro-power development. On the basis of the assessment of possible development trends for future power demand and power supply from other sources, and allowing for other user interests and environment-protection considerations, the Norwegian authorities would suggest a development ceiling of 125 TWh mean annual production capacity as a reasonable example of environment-favourable hydro-power development. Such a level of development would to a large extent correspond to hydro-power supplies in keeping with the future estimates for the year 2000.

The scale of investment in electricity supplies in recent years has been in the region of Nkr 2 per KWh on delivery to the consumer, at 1979 prices. Calculated in 1979 kroner, there is reason to believe that also in the future up to 1990 we can count on costs at about the same level. To cover a supply of firm power from new water power of a total of 20 TWh in the years from 1980 to 1990, about Nkr 40 000 million (1979 kroner) would have to be invested.

Power supplies of 20 TWh from hydro-power in the course of the 1980s are comparable with hydro-power supplies of 26 TWh in the 1960s and 22 TWh in the 1970s. In the period 1977-79 the average annual investments in the electricity sector were approximately Nkr 5 650 million (1979 kroner).

(ii) Coverage of oil products consumption

According to present plans the production of oil and gas on the Norwegian shelf will amount in round figures to 60 million tons of oil equivalents per year during the 1980s of which 60 percent, or about 35 million tons, will be oil. Given the petroleum reserves now calculated, we shall be able to maintain such a level at least until the end of this century.

Above all on economic grounds it will be desirable to mix North Sea oil with cheaper qualities of foreign oil, for example in order to obtain a range of products geared to Norwegian demand. In 1978, 15 percent of Norway's oil consumption was covered by Norwegian crude oil. As a net exporter of oil we are well placed to acquire the qualities and amounts of oil which it would be natural for us to purchase abroad.

(iii) Coverage of coal consumption

The primary domestic consumption of coal and coke is at present in the region of 1.3 million tons per year. Of this amount, in the first few years 300 000 - 350 000 tons per year will come from Svalbard. From 1982 production in Svalbard will increase to about 460 000 tons.

In the international context, Norwegian coal consumption is negligible. Norwegian needs should be able to be secured without any particular difficulty.

(iv) Contributions from other energy sources

Today other energy sources, above all wood, represent only 1 percent of our total direct energy consumption. For the year 2000 it has been suggested that from other energy sources, such as wind and wave energy, there could be a contribution to electricity supplies of 2 TWh or about 1.5 percent.

On the basis of the research and development effort now being made both here in Norway and not least internationally, and against the background of expectations of rising energy prices, it would be reasonable to base ourselves on an increasing contribution of this nature from other energy sources for direct heating purposes. Regard for resource economy and environmental effects, particularly when fossil fuels are used, points in the same direction. In the long run the energy sources which seem capable of making the greatest contribution in our case to heating purposes are biomass in the form of wood, chips, bark and waste, together with solar energy.

No estimate has been made of the future use of such energy sources. The contribution to heating by around the turn of the century, however, may be expected to be more or less on the same scale as the estimate in respect of electricity. If these sources prove to be a more profitable proposition, which could well be the case if oil prices continue to rise, it must be assumed that they will be used to a greater extent in the energy supply system. In that case the growth in the use of oil and coal, and possibly also hydro-power, could be correspondingly reduced.

CHAPTER 5

NORWEGIAN ASSISTANCE IN THE ENERGY FIELD

a) GENERAL

Norwegian assistance in the energy field has mainly been in the form of technical and financial assistance to specific projects in the main recipient countries of Norwegian aid. Assistance in the hydro-power sector, has so far been predominant.

Project support has normally been requested and identified by the developing countries themselves. In countries where the power sector is a major sector for cooperation, a more active part on Norway's side in project identification is foreseen.

b) HYDRO-ELECTRIC POWER

Norway's long experience in the field of hydro-electric power production and distribution systems has been the basis of its assistance in the energy field. The experience includes a large number of small-scale power projects. A programme for renewal of the old small-scale power stations in the country has recently started, and Norwegian manufacturers have for this purpose developed a range of standardized and semi-standarized hydro turbines as part of complete packages of small scale hydro-power stations that seem well suited for developing countries. Hydro-electric power development and production is largely a responsibility of the official sector. Consequently, the official sector posesses a considerable expertise in this field.

(i) Mozambique

Hydro-electric power development has been a priority sector of Norwegian development cooperation with Mozambique since 1979. In the first phase the cooperation will be concentrated to four areas:

- Technical assistance to strengthen the national power authority, Electricidade de Mocambique (EDM);

- Technical assistance within the overall planning of water resources and hydro-power development;

- Consultancy services for feasibility studies etc;

- Supply of equipment for the power development.

For the assistance towards strengthening of the EDM an agreement has been established between EDM and the Norwegian Water Resources and Electricity Board (NVE). The two institutions will exchange personnel at various administrative and technical levels to work for a certain period of time within the other institution.

In addition to the institutional cooperation with EDM, the following activities are supported:

- Hydro-power studies;
- Equipment for hydro-power development;
- Survey of potential hydro-power resources.

(ii) Tanzania

Power development has been a priority sector for the cooperation with Tanzania since 1976.

The major activity so far has been the planning and detail design of the Rufiji Multipurpose Development Project at Stiegler's Gorge. In addition, a request for development of small-scale hydro-power in two regions in the western part of Tanzania is under consideration.

Technical assistance has been given to the Rufiji Basin Development Authority (RUBADA) to enable this organization to carry out the planning of the contemplated development of the Lower Rufiji.

Under the Rufiji Basin Multipurpose Development Project the following main activities have been supported:

- Feasibility study of Stiegler's Gorge hydro-power project;
- Planning, detailed design and tender document for the power project;
- Necessary model tests of the power project;
- Seismological survey;
- Hydraulic survey;
- Mapping of the project area, incl. down-stream areas;
- Detailed design and tender documents for access road and bridge over the Rufiji river at Stiegler's Gorge;
- Studies on consequences of the power project in other sectors as agriculture, fisheries, forestry, ecology etc.;
- Macro-economic consequences of the project and ancillary investments.

2. In addition to the Rufiji project the following activities are on-going:

- Hydro-meteorological survey of the western regions of Tanzania;
- Elaboration of Water Master Plans for Rukwa and Kigoma;
- A request for small-scale hydro-power development in the same regions will be considered in light of the recommendation in the Water Master Plans;
- A request for planning and possible development of part of a high-voltage transmission line from Iorogoro to Nwanza has been received. This request will be considered after a clarification of the Stiegler's Gorge development has taken place.

(iii) Other countries

PHILIPPINES. Feasibility studies are being carried out for possible small-scale hydro-power development on the islands of Mindoro, Bohol and Antique. Request to finance some of the proposed developments has been received.

PAPUA NEW GUINEA. Feasibility studies for small-scale hydro-power development has been carried out for seven of the country's provinces.

In co-financing with the Asian Development Bank and other donors a grant amounting to 7.75 million dollars has been extended for the Upper Warangoi Hydro-power Project.

BURMA. Norway will participate with IDA and other donors in the Nyaungayat Dam Multipurpose Project to the tune of some 8 million dollars to finance the detailed engineering and design study of the Paunglaung Hydro-electric Project and power system planning and operations review.

THAILAND. As part of the IBRD Second Accelerated Rural Electrification Project Norway has agreed in principle to finance the construction of two mini-hydro power stations at a estimated cost of 1.6 million dollars. Formal agreement was concluded on 30 December 1980.

In future cooperation with the IBRD/IDA and the regional development banks, Norway will give priority to hydro-power development.

c) FUELWOOD

Norway has for several years been engaged in forestry projects, mainly in East Africa and India, but these projects have not been specifically aimed at fuelwood productionas such. However, the increasing recognition of the significance of fuelwood as a source of cheap energy in rural areas has led to a certain reorientation of NORAD's forestry projects towards such production.

d) FELLOWSHIP OFFERS

The following post-graduate courses in the energy sector are offered to students from developing countries:

- Hydro-power development (The University of Trondheim). 10 months course for candidates with B.Sc. in Civil Engineering and 2-5 years' experience in planning and/or construction of hydraulic works. The course consists of lectures, exercises, excursions and individual projects and aims at providing a good working background in planning, design and construction of hydro-power plants.

- Electric power distribution systems (The University of Trondheim). 10 months course for candidates with B.Sc. in Electrical Engineering and some relevant working experience. The course consists of lectures, exercises, excursions and individual projects and aims at providing a fundamental and practical background in planning and design of power distribution networks.

Figure 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.

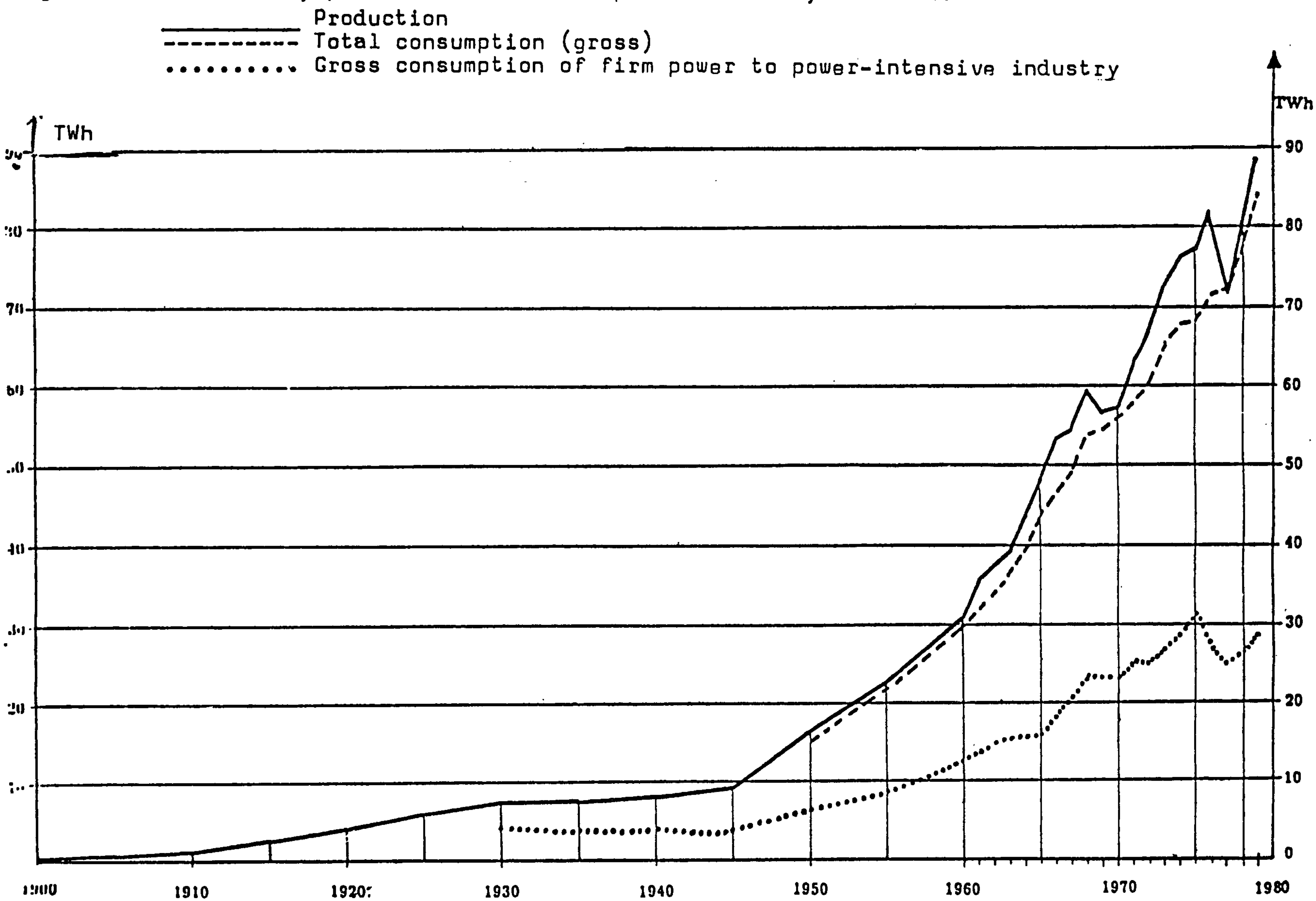
1978: Provisional figures.

Figure 3. 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.

Figure 2. Electricity production and consumption in Norway 1900-1979[1)]



1) For 1978 and 1979. Provisional figures

Figure 4. 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

Figure 5. Wave-power station. Groups of resonance buoys round a platform holding common pressure tanks, turbine and alternating current generator

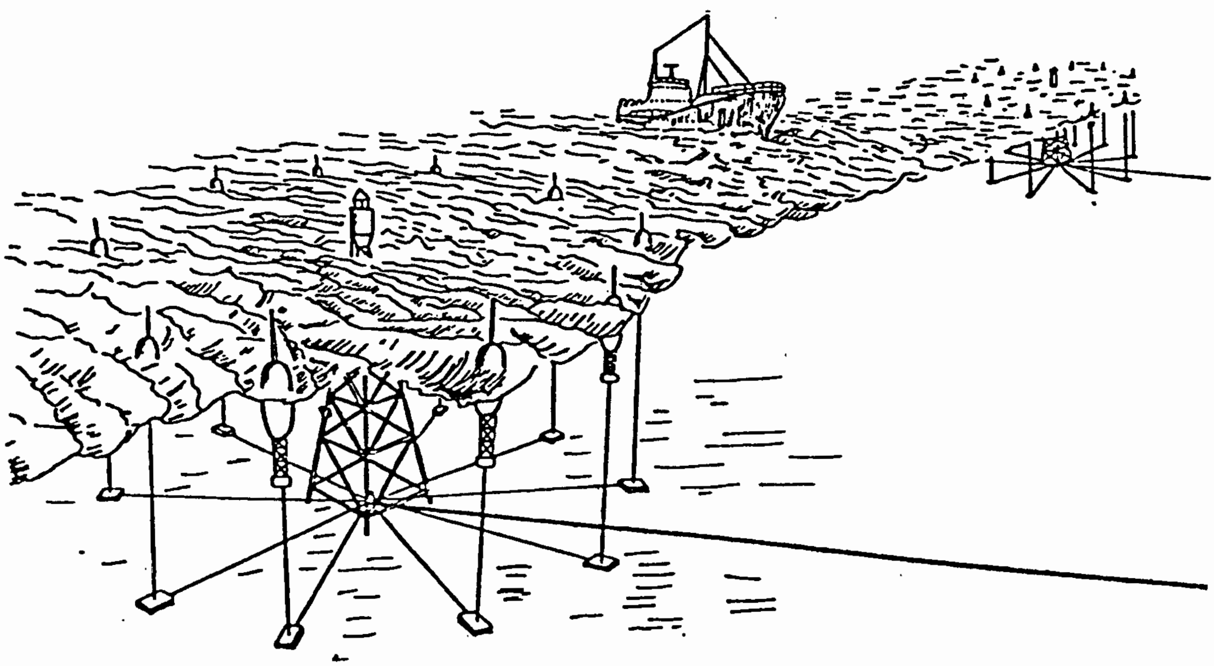


Figure 6. Wave-power station which gathers wave energy. A number of elements or "lenses" are anchored at a depth of 20-50 m.

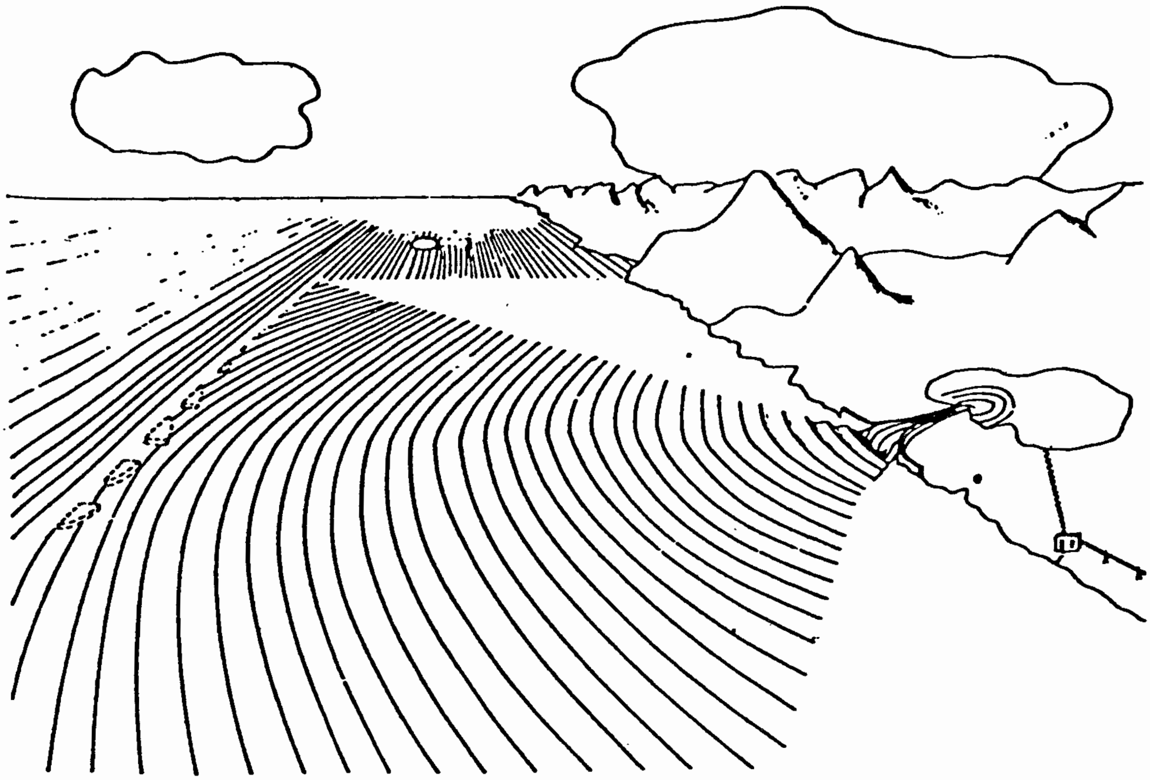


Figure 7. Illustration of possible usable energy from other sources around the year 2020

	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

Figure 8. 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.

Figure 9. Basic alternative for coverage of domestic firm power consumption. 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