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CONTENTS

NEW AND RENEWABLE ENERGY RESOURCES IN SWEDEN

0. SUMMARY

The long-term objective of Swedish energy policy is to reach a situation where Sweden's energy requirements are met by lasting, preferably renewable and indigenous, sources of energy with a minimum of environmental impact. The present high dependence on imported oil is regarded as unacceptable for a number of reasons, inter alia considering the future energy needs of the developing countries.

Significant measures have been taken in recent years with this objective in mind and with a view to eliminating the constraints that hamper a restructuring of the energy system.

Hydro-electric power is Sweden's most important indigenous source of energy. Hydro-power presently accounts for two-thirds of total electricity production (61 TWh in a year with average precipitation). Production 1990 is expected to be 65 TWh. The forests are Sweden's most important natural resource and they also play an important role as a source of energy, particularly in the pulp & paper industry. It is expected that utilization of indigenous solid fuels (forest residues and peat) will increase considerably during the 1980's. Solar energy for heating purposes and wind power are expected to make small contributions by 1990.

The rate of introduction of new and renewable energy sources depends to a large extent on the competitiveness of such energy sources in relation to conventional energy, and on how this relationship is perceived in the long term. It also depends on the priority accorded to new and renewable energy within national energy policies.

Measures taken by the Swedish Government to overcome constraints that limit the introduction of new and renewable sources of energy include economic incentives as well as considerable R & D-efforts aimed primarily at technical development and environmental issues. The main emphasis of the Swedish energy research programme

is placed on renewable energy.

The Swedish Government attaches great importance to a further development of international cooperation in the field of new and renewable sources of energy. It is fully recognized that strong measures are needed by developed countries and by the international community with a view to promoting the development of both conventional and non-conventional energy sources in developing countries. SIDA - the Swedish International Development Authority - has adopted specific guidelines for energy assistance. SAREC - the Swedish Agency for Research Cooperation with Developing Countries - provides assistance for strengthening indigenous research capacity in developing countries i.a. in the field of energy. The Swedish Commission for Technical Cooperation has supported several projects in the field of renewable energy.

I. INTRODUCTION

The long-term objective of Swedish energy policy is to reach a situation where Sweden's energy requirements will be met by lasting, preferably renewable and indigenous, energy sources with a minimum of environmental impact. With this objective in mind, the Swedish energy programme aims primarily at reducing dependence on imported oil through energy conservation and through development of alternative sources of energy, both conventional and nonconventional.

The Swedish Government is firmly committed to a profound restructuring of the Swedish energy system as part of a global effort to ensure adequate energy supplies and continued economic growth for all countries. The present Swedish reliance on oil is regarded as unacceptable, considering the long-term supply and demand prospects and against the background of the energy requirements of the developing countries.

Energy policy issues have been intensely discussed in Sweden in recent years. There is a wide recognition that the world is confronted with serious problems in the energy field, and that a transition away from oil is necessary, both from a national and an international point of view. There is wide support for determined policies and measures to strengthen energy conservation and to develop new and renewable sources of energy.

At the same time, it is recognized that a number of constraints hamper a rapid restructuring of the energy system and that the process of restructuring by necessity is time-consuming. It is also recognized that significant further efforts in the field of research, development and demonstration are needed in many instances before most new and renewable sources of energy can become competitive and before a significantly higher contribution from such sources of energy can be attained.

II. STATUS AND OUTLOOK

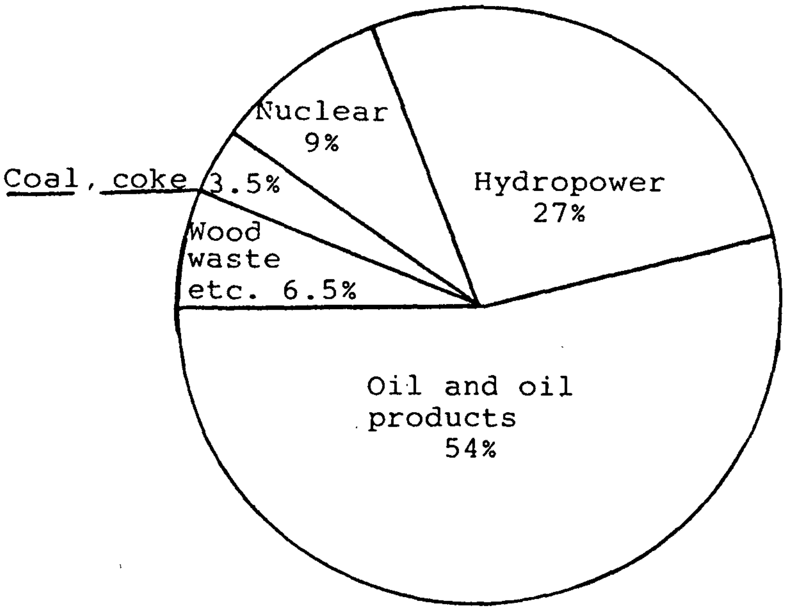
The energy consumption, excl. losses, in Sweden ("Table 1") is around 1450 PJ (35 Mtoe). About 50 % of the total primary energy requirements and 70 % of the fuel requirements are based on oil.

"Table 1".

Sector	PJ	%
Transport	255	18
Industry	556	39
Residential and commercial	619	43
Total use	1.430	100
Losses		
Conversion	90	
Non-energy	41	
Bunkers	37	
TOTAL	1.598	

There is hardly any oil, gas or coal in Sweden. On the other hand, the country is fairly rich in non-conventional 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 transistion to an energy system primarily based on indigenous and renewable sources.

"Figure I". Sources of the Swedish energy supply in 1979 (with hydropower and nuclear power counted in fossil fuel equivalents).



Several studies of the potential of new and renewable energy sources have recently been made 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:

(1) those, which can be used immediately with known technology (forest and agricultural residues, peat and refuse)

(2) 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)

(3) those, for which possibilities can only be estimated after certain R & D period (energy forests, photovoltaics, wave and geothermal energy, etc.).

"Table 2" shows the Commission's estimates for the year 1990. "Table 3" gives the Commission's assessment of the technological status for several new sources of energy.

"Table 2". Estimated contribution 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)

Provided that development efforts are successful, considerably higher contributions can be expected by the year 2000.

"Table 3". 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		

Already now, the sun provides more than one fifth of Sweden's total primary energy in the form of hydro-electricity and forest waste. There is a large future potential for energy forest plantations since the availability of suitable land on a per capita basis is large. In addition some 50 % of Sweden is already covered by forests, and other areas of interest include closed down agricultural land or peat-bogs.

In the following section of this paper, each renewable energy source will be discussed in detail with respect to resources, technical and economic feasibility, as well as with regard to environmental and institutional issues.

SOLAR ENERGY

Solar heating

Roughly 40 % of the energy consumed in Sweden, or approx. 570 PJ (14 Mtoe), is used for heating, ventilation and hot water production in buildings. As matters stand today about 65 % of the heat is supplied by individual oilfired boiler installations. District heating plants supply approx. 25 %, while electric heating accounts for the remaining 10 %. Since 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 %. In order 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 approx. 1 kW/m2 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 approx. 0.1 kW/m2 horizontal level. Despite the fact that Sweden's northern position results in an unfavourable distribution of solar radiation between summer and winter, the number of sunshine hours is comparable with that in large parts of Central Europe, but less than that in Southern Europe, the USA and Japan. About half the annual solar irradiation is supplied during Sweden's approx. nine-months long 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 for another the heating medium, water, permits the use of established district heating technology. These huge storages can be conceived according to different principles. Within the energy R & D programme, studies are currently under way 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 - 10.000 m3.

Storage in and heat recovery from soil includes not only methods involving active storage in soil, rock caverns and ground water stores, but also heat recovery from "passive" storages i.e. soil, rock caverns, lake bottom sediments, surface and ground water, etc. with heat supply from the natural irradiation. Such passive storages constitute heat sources for heat pumps, which can then 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 is nevertheless 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 economic. However it has one disadvantage in that relatively large areas of ground have to be used. A normal private home requires a 400 m tube coil occupying an area of 400-500 m2.

Other "passive" storage systems are also being investigated within the energy R & D programme. 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 ground water as a source for heat pumps is also being studied.

Among the active storage systems, deep level heating systems has made considerable progress and several experimental building projects have been completed. They are expected to be roughly 30-40 % 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 can thus be used to "charge" the storage unit, which can then be sealed and tapped at any time.

Solar collectors. Industrial production of solar collectors has been 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, since 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 is therefore devoted to the long-term characteristics. Intensive development work is under way with the aim of reducing problems of corrosion, leakage, thermal expansion, etc.

Some Swedish companies also market complete systems for solar heated tap water. Among the systems installed in Sweden, those for single-family buildings predominate (approx. 2.000). Systems for heating of swimming pools are also being developed.

Within the energy R & D programme, development is also 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 45-60 ^{o}C to 75-80 ^{o}C, with the culvert system subsequently functioning as a heat storage. By this means, approx. 10 % 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, there were roughly 10.000 heat pump units 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 hundreds 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 is also being developed. In comparison with other types of heating plants, the installation cost for the heat pump is high. The installation cost is roughly 3-5 times greater than for an oil-fired plant.

Passive solar heating. The need for conventional heat supply may be reduced by up to 30 % 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 R & D programme, 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 of 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, e.g. in private houses and multi-family dwellings, in new buildings and existing buildings etc.

The objective of the energy R & D programme 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 80-120 $/barrel of oil equivalent.

The cost of solar heated tap water for the systems already installed is 120-160 $/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 60-80 $/barrel, of oil equivalent.

Energy contributions. The uncertainties as to the development of different solar heating technologies to which reference has been made above 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 (0.2 Mtoe) can be produced with solar energy by 1990, primarily in district heating systems and for heating of tap water. By the year 2000, the production may be at the rate of 35 PJ (0.8 Mtoe) per annum, a large proportion of which will relate to systems with year-round storage.

Solar power

This heading relates to solar energy which is converted directly into electrical energy or fuel (e.g. hydrogen). Solar power technology may be divided into three sub-areas: thermal solar power stations, semiconductor cells and photochemical systems.

Thermal solar power. Sweden is participating in an 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 energy-richer substances. 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 photo-chemical 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 favourable circumstances account for a few tenths of a TWh. The other methods are not expected to be able to give any contribution. In the long-term perspective, the photo-chemical processes may nevertheless acquire some importance.

HYDRO-ELECTRIC POWER

Sweden has ample supply of hydraulic (hydro-) energy, particularly in the northern parts of the country. Hydro-electric power was developed at an early stage and has been a basis for the industrialization of Sweden. A nation-wide 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 all around the world in consulting, construction and equipment for hydro-power projects and electricity transmission. As matters stand today, hydro-electric power has been exploited for an annual production of more than 215 PJ (60TWh). A technical potentional exists for an increase of annual production to 470 PJ (130 TWh), of which 340 PJ (95 TWh) is economic at present-day energy prices. However, in order to preserve wild life and the natural environment, Parliament has decided to impose restrictions on the further expansion of hydro-power. It is expected that hydro-electricity production in 1990 will be around 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 per cent, or 54.000 Mm^2, of Sweden's total area consists of marshland. This marshland varies in age from a few thousand up to ten thousand years. The annual rate of growth is 0.1-0.5 mm, the implication being that in practical terms peat is a non-renewable resource. The thermal value of the peat resources is estimated to be equivalent to some 3.000 million tons of oil. Swedish peat resources are currently 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 both in Sweden and elsewhere. The Swedish peat industry expanded rapidly during World War II and at most, in 1945, produced 1.5 M 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 R & D programme 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 impoving and full-scale trials are planned. Efforts are also being made to improve peat-combustion, particularly in medium-sized furnaces (0.1-1 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 consequenses 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 plant.

In Sweden, energy from peat is currently at an introduction stage. Several new extraction- and combustion projects have been started during the last few years. By 1990, it is estimated that the amount of peat being used could be equivalent to 20-50 PJ (0.5-1 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 9-17 $/ 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 can now compete with both coal and oil.

BIOMASS

Wood waste etc.

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 m^3 per year (544 PJ or 13 Mtoe). The total growth is estimated at 120 million m^3. In a corresponding manner, Sweden's timber store may be estimated at 3.800 million m^3 of biomass (27.600 PJ or 660 Mtoe).

In the Swedish forestry sector, 75 million m^3 of timber and pulpwood per annum is harvested for use by the forest products industry. By-products are used by the industry to a very great extent as fuel (1979: 110 PJ or s.6 Mtoe).

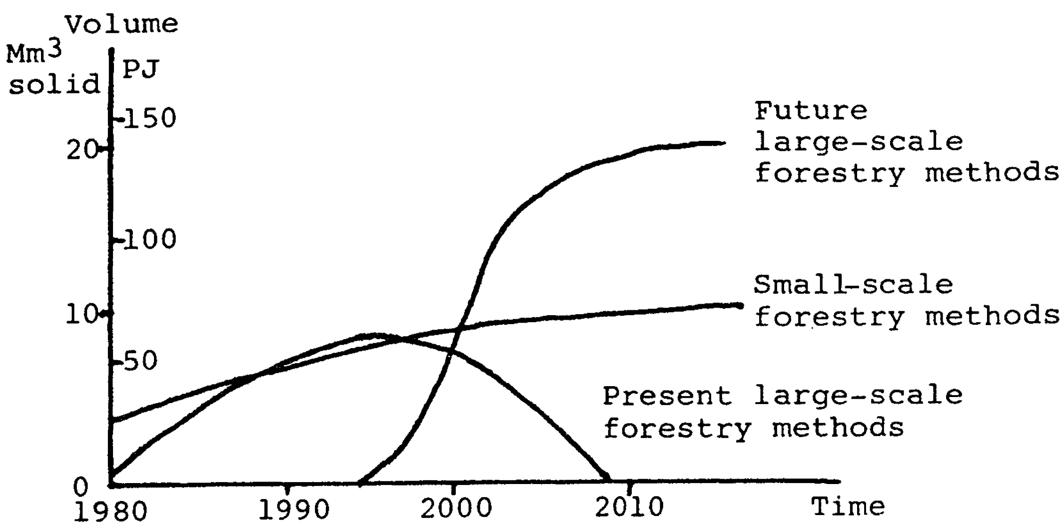
Approx. 45 million m^3 in the form of roots, felling residues, clearing and thinning timber, deciduous trees, etc., are left on the felling sites. The energy content of these residues amounts to approx. 325 PJ (7.8 Mtoe).

Present-day forestry uses the so called assortment method, according to which limbing and sawing of the logs into standardised lengths and quality classes takes place on the felling site. Organised utilisation of forest energy is taking place experimentally. Individual forest owners and private individuals collect residual wood from clearfelled areas for use as fuel. Similarly, minor quantities of smallwood trees in clearings and wood left behind after logging of merchantable timber are collected. At the end of 1979, annual consumption of wood and chips used as fuel was estimated at 4 million m^3 solid measure under bark (30 PJ or 0.7 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 stum 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 m^3, can be collected. The exploitation of forest energy is expected to develop as shown in "Figure II".

"Figure II".



The total yield with present-day felling methods is expected to stagnate at 17 M m^3, equivalent to 120 PJ (2.9 Mtoe). With the current level of oil prices utilization of this source of energy in Sweden is economic in many instances but it may temporarily be constrained by technical and infrastructural factors.

Future logging methods, such as the "whole tree" and "part tree method", would enable a greater proportion of the tree residues to be extracted for energy purposes. (26 Mm^3/solid measure under bark per annum, equivalent to 190 PJ or 4.5 Mtoe). As part of the energy R & D programme, considerable efforts are currently being devoted to improved felling techniques (i.e. the so called whole tree method). These effects aim at development and full-scale testing of a "first generation" new technology by 1987.

Forest energy based on forest residues etc. is primarily expected to be used in hot water centres, district heating plants, industrial boilers and on farms as substitute for oil and coal. If this is to be acheived 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 centres 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 such 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 as to 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 technique, the production costs are usually in the range of 11-23 $/barrel of oil equivalent. Preparation and conversion costs must be added in order 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 which have been specially selected because of their rapid, high-energy fibre 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, inclination, etc.) are favourable, of large coherent areas of densely cultivated deciduous forest. They require a growth period after planting of 1-3 years before they can be harvested for the first time. In a steady-state stand, harvesting cycles of 1-3 years are likely. Each cultivation is expected to have a growth-favouring life duration of 20-30 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 is currently under way 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, i.e. 60 m^3 per year and hectare, which is considerably in excess of even the highest of previously observed production volumes in forestry in cold climate areas.

As part of the energy R & D programme, 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.

Since energy forest cultivation is a new field of activity both 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 R & D programme.

Prior to use, the harvested fibre mass has to be fractionated (e.g. chipped), prepared (e.g. dried), stored and transported.

The ecological and environmental problems related to energy forest cultivation - influence on ground water, nitrite leakage, insect combating, protection of plantations against voles, elks, etc. - are being investigated as part of the energy R & D programme. Environmental restrictions may prove to be an obstacle to high-intensive cultivation on peat land.

Energy forest cultivation is currently 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 approx. 3 M tons dry substance or a good 50 PJ (1.2 Mtoe) may be produced by the year 2000. Estimates of the production costs vary between 7-36 $/barrel.

Energy from agriculture

Straw. In Sweden, straw cereals are cultivated on approx. 1.5 million hectares. The production of straw is approx. 4 tons/hectare, i.e. a total of 6 million tons per year. A significant proportion of this volume is currently ploughed back into or burnt on the fields. It is assumed that between a third of and half the annual production of straw could be harvested for combustion, implying an energy contribution of approx. 40 PJ (1 Mtoe). Straw has long been marketed on a

Commercial basis and strawfired boilers are available 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 labour 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 14-22 $/barrel of oil equivalent.

Biogas etc. Farm yard manure can be fermented to produce methane gas. The total potential of farm yard manure is estimated at approx. 54 PJ (1.3 Mtoe). At present there are several pilot plants in operation in Sweden. One of the reasons why it is expected that this technique will be used only to cover the energy requirements of a small number of larger farms is the difficulties encountered in distributing the gas.

In recent years there has also been an increasing interest to use waste products from the sugar industry for energy production.

Energy crops. Energy crops 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 hamp.

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 steadily increasing at the rate of approx. 50 kg dry substance/hectare and year.

With the Swedish climate and current carbon dioxide contents of the atmosphere, it is believed that the limit lies at around 25 tons dry substance/hectare and year compared to the current 5-10 tons. It is estimated that approx. 700,000 hectares could be used for other production than food stuffs by 1990.

The energy R & D programme also embraces research concerning crop selection and crop rotation, soil characteristics, production yields, environmental consequenses, 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, the use of biocides, etc. 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 approx. 100,000 hectares, which with a yield of approx. 5 tons dry substance/ hectare, gives 9 PJ (0.2 Mtoe)/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 work load 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 R & D programme 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 programme is concentrated on building big land-based plants connected to the electric power grid. An evaluation and testing programme 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 comleted by the spring of 1982. They are twin-bladed, horizontal axis power stations with a tower height of approx. 80 m, a turbine-blade diameter of 78 m and a rated output of 2.5 and 3 MW respectively. They differ from each other in respect of the materials chosen for the tower, turbine blads and hub.

Detailed knowledge about wind conditions is an essential basis for any significant wind power programme. A large-scale measuring programme 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 3-7 cents/kWh excluding costs for power reserves. The uncertainty interval for the cost of wind power is due to the considerable uncertainty in estimating power-station costs, wind conditions and annual production. The potential for wind power is estimated at approx. 110 PJ (30 TWh) in Swedish land areas with wind velocities in excess of 7m/sec. The potential in marine areas is believed to be roughly the same. If the R & D programme gives favourable 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 currently being tested.

The wave energy reaching the Swedish coast is very modest in an international comparison, approx. 4 kW per meter wave front during the ice-free period.

Utilization of wave energy is still surrounded by a large number of uncertainties. The plants will have to be constructed to resist storms, ordinary wear, corrosion, icing etc. The potential for Sweden has been estimated at approx. 10-55 PJ (3-15 TWh) per year at a cost of 6 cents/kWh.

Conceptual design work has been carried out on salt and thermal gradient energy, but neither seems to be feasible in the Swedish cold and brackish waters.

Swedish industry participates in the international Ocean Thermal Energy Conversion (OTEC) development. The Swedish contribution is mainly concentrated to advanced heat exchanges and turbines.

GEOTHERMAL ENERGY

In the south of Sweden, deep layers of sandstone which contain hot water can be found in the sedimentary bedrock. The heat content amounts to approx. 7,200 PJ (170 Mtoe) for temperatures above 50 °C and approx. 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.

III. CONSTRAINTS LIMITING THE INTRODUCTION OF NEW AND RENEWABLE ENERGY SOURCES

Against the background of the political commitment to move the Swedish energy system towards a much greater reliance on new and renewable sources of energy, analyses of constraints that limit the introduction of such energy sources obviously assume great importance. In this section, a more systematic survey of constraints will be made on the basis of Swedish experiences. It should be pointed out that conditions vary from country to country and that constraints might be perceived differently under other circumstances than those prevailing in Sweden.

The rate of introduction of new and renewable energy sources depends to a large extent on the competitiveness of such energy sources in relation to conventional energy, and estimates concerning future price developments are of great importance for the role that new and renewable energy sources could play. However, it must be recognized that the availability of cheap oil in many countries has shaped existing energy infrastructures as well as the distribution and consumption patterns, and that time and specific measures are required to adapt the energy system to new energy carriers and new price relationships.

The Swedish Government has concluded, for a number of reasons, that it is not possible to rely only on market forces for this adaptation to take place. Strong and determined long term energy policies with increased reliance on durable, preferably renewable and indigenous, sources of energy as a major objective have been regarded as indispensable if the transition is to be achieved without adverse effects and if the constraints are to be overcome. It has been concluded that firm policy guidance and considerable resources are needed to this end.

The constraints limiting the introduction of new and renewable sources of energy could be divided into the following groups:

- political
- economic
- environmental
- technical
- procedural
- organizational and marketing
- socio-political

The political constraints relate to the need for governments to establish concrete objectives and guidelines in order to reduce uncertainties at all levels, and also to the availability of geovernment incentives to induce municipalities, companies and consumers to swith to renewable energy.

Economic constraints are of great importance, particularly considering the investment cost if it is envisaged that renewable energy sources should replace conventional energy. The future development of costs for conventional fuels and alternative fuels is a question of great importance, and also a source of uncertainty. Difficulties might occur in financing the necessary investments.

Environmental constraints relate to the need to assess adverse effects on the human environment, the need to take additional measures to meet requirements established for environmental reasons as well as the cost of such measures, and to uncertainties with regard to such environmental standards.

Technical constraints relate to the status of technology in relation to available physical resources of various kinds of energy. The availability of physical resources of renewable energy of course varies from region to region and from country to country, which means that a specific technology could be economic in one region or country but not in others. Generally none of the technologies to be discussed at the Nairobi Conference requires technical breakthroughs. On the other hand, further research and development efforts are necessary in many instances in order to make these technologies more competitive and reliable.

Procedural constraints concern the often timeconsuming process of obtaining necessary licenses and permits from central and local governments.

Organizational and marketing constraints relate mainly to problems connected with the creation of markets for new forms of energy and the availability of viable organizations and institutions which have an interest in the introduction of such sources of energy.

Socio-political constraints concern the way in which a new technology is accepted by the general public and how it fits into existing social patterns.

The possibilities to use a given physical resource of renewable energy are limited to a varying degree by each one of the abovementioned constraints. Swedish experiences indicate that it is important to take into account all kinds of constraints at an early stage in energy planning.

IV. MEANS TO OVERCOME CONSTRAINTS

A number of measures have been taken in Sweden in recent years in order to encourage the introduction and utilization of new and renewable sources of energy. These measures aim at eliminating, or reducing the importance of, the constraints referred to in the previous section of this paper.

In a major energy bill to Parliament, the Swedish Government has recently reaffirmed its determination to reduce dependence on imported oil and to increase the reliance on durable, preferably renewable and indigenous, energy sources with a minimum of environmental impact. In the bill, it is also confirmed that a high priority will be attached to energy conservation.

In the bill, it is estimated that 3 million tons of oil will be replaced by indigenous solid fuels (forest residues and peat) by 1990. The considerable utilization of bark and liquors as fuel in the pulp & paper industry will continue (approx. 3,5 Mtoe). Hydro power production is expected to increase from 61 TWh annually today to 65 TWh in 1990. Solar heating is expected to contribute roughly 0,2 Mtoe and wind energy 0 - 1 TWh.

Several steps are proposed in the bill in order to encourage a wider utilization of renewable sources of energy, mainly in the fields of indigenous solid fuels from biomass and solar heat. A new law is proposed according to which new boilers of a certain size must be designed to use solid fuels. New proposals are being presented concerning research, development and demonstration.

Over the years, several measures have been taken by the Government in order to create economic incentives to switch from oil to other sources of energy. Grant schemes for i.a. oil substitution in industry and prototypes and demonstration plants have been in operation since 1974. These schemes have recently been replaced by a special "oil substitution fund", which will be financed through a fee on oil consumption and which will provide loans on favourable terms, and in certain cases where technological risks are considerable also grants, in order to promote a further rapid substitution of other energy sources for oil. It is estimated that the fund will have around 375 million US $ at its disposal during the first 3 year period. Taxes on oil have been increased several times in recent years in order to reinforce the shift towards other sources of energy.

The Swedish efforts in the field of research, development and demonstration focus on most of the constraints referred to in chapter III, but mainly on further technological development. Particular attention has also been devoted to environmental, health and safety aspects of new and renewable sources. According to figures published by the International Energy Agency, Sweden´s total government-supported R & D effort in 1979 in the field of new energy technologies amounted to 13 US $ per capita, which puts Sweden behind only the US and the Federal Republic of Germany. The main emphasis of the programme lies on the development of renewable sources of energy and on energy conservation. Efforts in the fields of indigenous fuels (natural or cultivated biomass, peat etc.), solar heating and wind energy account for approximately 50 % of the programme.

"Table 5". Subdivision of the Energy R & D programme. Million US $.

Programmes	Funds for the period 1975/78	Funds for the period 78/81	Proposed funds for the per 81/84
Energy use in Industrial Processes	10,2	23,3	38,0
Energy use for Transportation	6,1	8,3	15,5
Energy use for buildings	16,0	36,5	56,8
Energy supply	50,8	107,9	155,5
Energy system studies	1,5	3,5	5,5
Fundametnal research	4,0	7,1	11,1
Planning and coordination	1,4	2,8	3,3
International cooperation and other efforts related to the Main Programme	5,1	8,7	-
Funds for later distribution	-	-	25,0[1)]
Total budget	95,1	198,1	310,7

1) Including funds for international cooperation

In the field of indigenous fuels, activities cover a range of fields from use of forestry residues and waste and short-rotation-forestry for energy purposes to processes and technology to use or up-grade (gasification, liquefaction) the indigenous fuel feedstocks. Support has also been given, within the R & D programme, to the establishment of companies for the large-scale distribution and marketing of indigenous fuels.

V. SCOPE FOR INTERNATIONAL COOPERATION

If the long-term global energy problems are to be solved, international cooperation aimed at promoting the development of new and renewable energy sources will have to be vastly expanded. Such cooperation must be geared both to concerted efforts with regard to research & development and to an increased utilization of new and renewable sources of energy on the basis of existing technologies.

As pointed out earlier considerable efforts are necessary before renewable energy sources can make a significantly greater contribution to Sweden's energy needs. Bearing in mind the resources required for such efforts, it is of great importance for Sweden to participate actively in international research & development projects and to draw upon results achieved and work undertaken in other countries. Sweden contributes substantially in several areas of international energy R & D cooperation.

Within the framework of the International Energy Agency, considerable progress has been made in recent years in establishing a large number of concrete cooperative sources of energy. Sweden participates actively in most of these projects.

The Swedish Government fully recognizes the need for rapid and strong measures by developed countries and by the international community to promote the development of both conventional and non-conventional sources of energy in developing countries, in particular the development of indigenous energy resources in oil-importing IDC's. With present trends, it appears quite clear that the cost and availability of energy is becoming a major constraint on the economic and social development of many countries. In order to avoid such a situation, which would entail grave risks and dangers, action is necessary in a number of important fields, not least the ones to be discussed at the UN Conference on New and Renewable Sources of Energy.

On various occasions in recent years, the Swedish Government has underlined the importance of development assistance in the field of energy. Against this background, SIDA - the Swedish International Development Authority - has developed specific guidelines for energy assistance to the so called programme countries, i.e. the countries receiving Swedish bilateral assistance on a priority basis.

In these guidelines, it is noted that SIDA has been working for a long time with the development of hydropower, forestry and reforestation in developing countries against a background of considerable Swedish experience and know-how in these fields. In the future SIDA will be ready to offer assistance aimed at strengthening the energy planning of the programme countries. Furthermore, SIDA will continue to support FAO and the programme countries in order to ensure even exploitation of forests, improved forestry and increased reforestation. SIDA will also continue to support large hydro-electric plant-projects as well as small-scale plants in the rural areas. Also projects involving other renewable sources of energy could be considered. The importance of the interest of the programme countries for a further development of assistance in these fields is underlined.

In connection with all development and production of energy, relevant aspects of energy conservation, environment, health, education and the active participation of those groups of the population who are affected, as well as short-term and long-term socioeconomic effects will receive attention.

The Swedish Agency for Research Cooperation with Developing Countries, SAREC, provides assistance for strengthening indigenous research capacity i.a. in the field of energy. Projects so far include the exploitation of geothermal energy, the use of producer gas and development of solar crop dryers. Financial assistance has also been granted to projects in other fields, e.g. studies on the fuel-wood cycle and small-scale hydroelectic units.

The Swedish Commission for Technical Cooperation, a body set up to promote cooperation between Sweden and certain developing countries in the fields of pre-investment studies, training and other types of cooperative projects of mutual interest, has granted support to several activities in the fields of hydro-power and forestry.

The Energy R & D Commission - i.e. the body set up to coordinate the Swedish energy research programme - has been charged by the Government to pay particular attention to the possibilities for research cooperation with developing countries within the framework of this programme. The Government has recently proposed that certain funds should be earmarked for cooperative R & D activities with developing countries.

The Swedish Council for Building Research (BFR) is responsible for the part of the R & D programme dealing with energy use in buildings.

Address: The Swedish Council for Building Research
(Statens råd för byggnadsforskning)
Sankt Göransgatan 66
S-112 30 STOCKHOLM
Sweden

The Transport Research Delegation (TFD) is responsible for the part of the R & D programme dealing with energy use in the transport sector.

Address: The Transport Research Delegation
(Transportforskningsdelegationen)
Sveavägen 166, 14tr
S-113 46 STOCKHOLM
Sweden

The Government has recently proposed a streamlining of the organizational structure among government energy agencies. A new government agency - the National Swedish Energy Board - will be established from July 1, 1982. Resources and staff will be transferred to the new agency from i.a. the Energy R & D Commission, the National Board for Energy Source Development, the Oil Substitution Commission, the Committee on Energy Conservation and from the National Swedish Industrial Board. All these agencies except the latter one will be dismantled. A special body will be created for questions concerning long-term energy research with resources taken from the National Board for Energy Source Development. A separate organization will also be created for the Oil Substitution Fund.