POSSIBILITIES OF UTILIZING RENEWABLE ENERGY SOURCES

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Introduction

The utilization of renewable energy sources, to varying degrees in the various periods, has run through all the history of mankind.

Human settlements were formed and began to grow first at places where natural environments including the facility of renewable energy sources provided direct means of subsistence.

Technical progress, however, promoted the formation of human settlements also in areas where conditions were infavourable. Mechanical work required by production was to be effected at a more and more advanced level and this necessitated the use of water- and wind-wheels so as to replace manpower and animal strength. Simple steam-engines, like that of Papin, which served to lift water for the water wheel by the use of steam energy started off the steam engine on its way of independent development and the introduction of coal heating opened the prospects of its wider use. Naturally, this latter stage of development lead to a basical change also in the form of energy sources to be used.

1. Structure Changes of Utilized Energy in the World

During the last two centuries the demand for fuel and other forms of energy used by man underwent considerable changes not only in relation to quantity but also in relation to structure.

1.1. *Quantitative and structural changes of utilized energy*

Quantitative changes are shown in Fig. 1 and 2 [1, 2, 3]. Structural changes can be seen in Fig. 3 [4]. Increasing concentration both in the field of power production and consumption is a typical feature of technological improvement. About two hundred years ago ten per cent of all used energy comprised non-renewable energy while today's figures show that ninety per cent of utilized fuel and energy sources cannot be regenerated. Structural

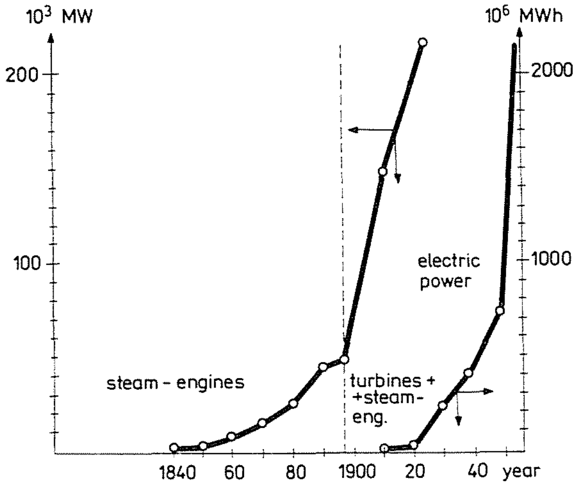

Fig. 1. The change of total power production of the world's steam-engines and turbines (on the left) and total electric power production of the world (on the right)

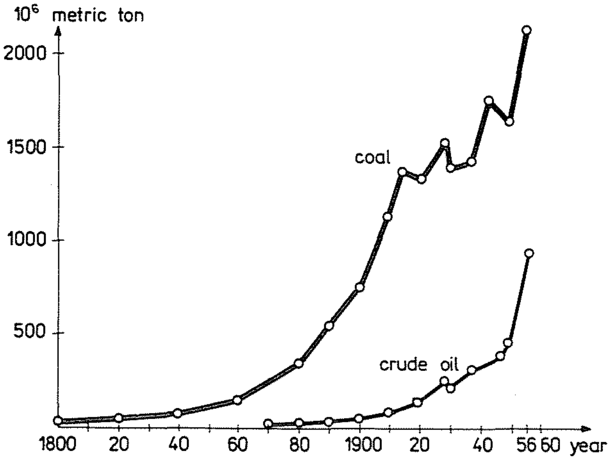

Fig. 2. Development of coal and crude oil production of the world

changes are influenced by a number of factors. Such are, apart from power machines and the improvement of technology, economic efficiency during the period given, economical and political competition and others. This has been demonstrated by the change over from water and wind energy to coal and oil power by means of steam-engines. At the same time, decrease in the volume of energy sources also reacts to the trends of utilization. As it is nowadays when the fall in crude oil reserves results in a re-increasing utilization of coal power and in a tendency to turn to nuclear power as one of the energy sources of the future. This can be seen in Fig. 4 which shows the change of estimate trends in the energy structure of the world before the "energy crisis" (on the left) and after it (on the right). At the same time, the use of renewable energy sources, as hidraulic power, wind, solar, geothermal, tidal, oceanothermal and biomass energy also presents itself as an actual possibility.

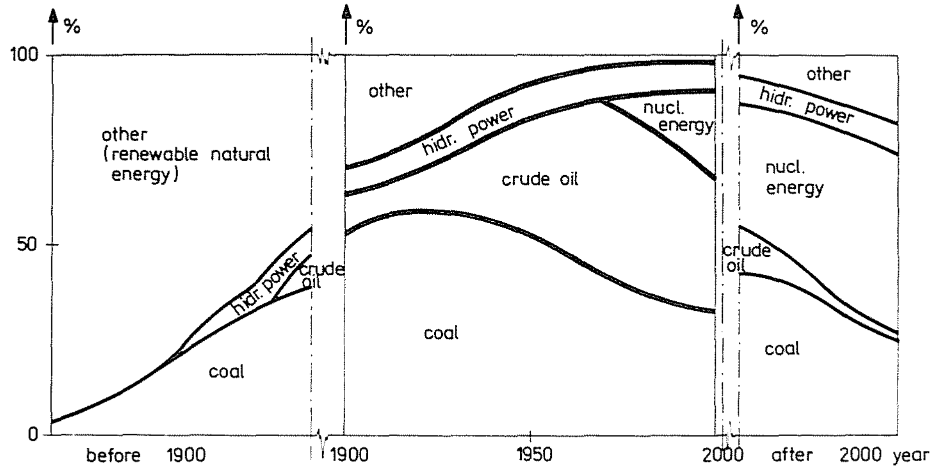

Fig. 3. Structure changes of utilized energy in the world during the centuries and the estimate trends in energy structure in the future

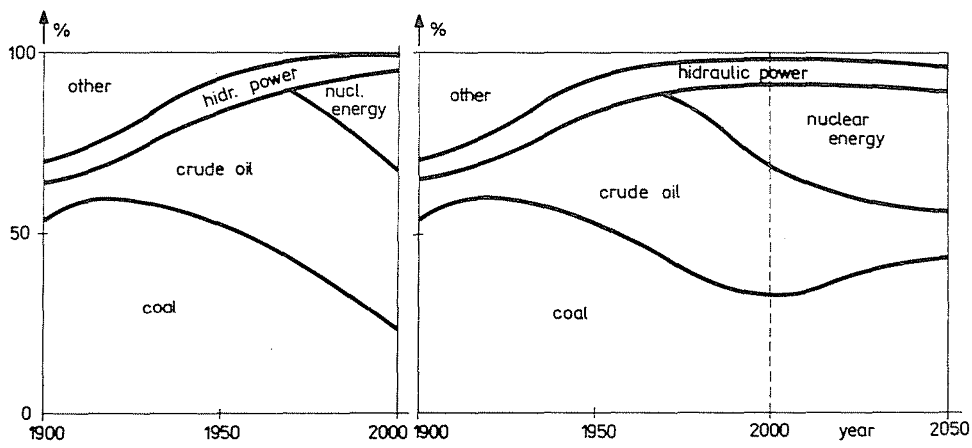

Fig. 4. The change of estimate trends in energy structure before (on the left) and after the "energy crisis" (on the right)

1.2. *Structure changes of utilized energy in Hungary*

The tendencies outlined here in relation to the world situation can of course alter according to places or can even basically differ from one another. Figure 5 shows the changes in the structure of energy in Hungary in the second half of the century, as compared to the energy structure in the world before and after the "energy crisis". It seems, after all, that a renaissance is to be expected in the utilization of renewable energy sources in the following century. It is partly due to the situation in the world but is also promoted by achievements in the field of material and production technology during the last few decades.

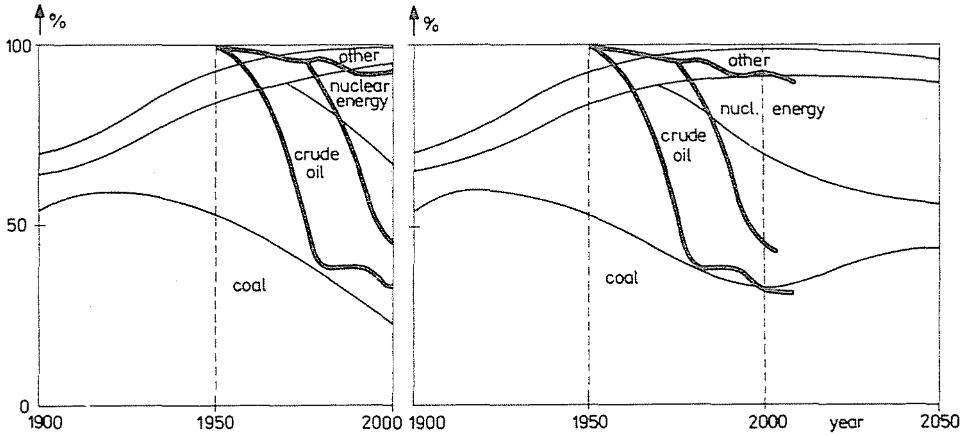

Fig. 5. Changes in the structure of energy in Hungary during the second half of this century (heavy line) as compared to the energy structure of the world before and after the "energy crisis" (thin line)

2. Possibilities of the Utilization of renewable Energy Sources today

2.1. *Development of utilization of renewable energy sources*

It is obvious from what has been said so far that the rate of energy consumption based on renewable sources has been reduced since the rapid rise in the use of non-renewable sources even though it has been promoted by technical progress. Due to cooperating energy systems, however, the need for non-renewable energy was not brought up as an objective and pressing necessity, therefore in our days the efforts to utilize them leave us with results of local importance only, or come up as fashion from time to time, without providing any solution in the energy problems. Wider utilization of renewable energy sources can only be expected by the next thousand year when the utilization of non-renewable energy sources will be determined by more reasonable aspects than those of today.

Renewable energy sources (for example water, geothermal, oceanothermal, solar, wind or what is still little applied today, obtaining gases out of biomasses) will be an addition to basic energy sources (as nuclear energy and coal power). Or, depending on geographical and other factors of the energy consumer, they can be of primary importance while non-renewable energy sources will serve as auxiliaries. We can find example for this in the early stage of technical development. As it is well known, pumps were driven by windmills in the Netherlands in the battle against the sea, and steam-engines were used only as an additional source of power.

2.2. *Spatial distribution of non-renewable energy sources*

Before going on to the utilization of renewable energy soources, let's glance through the question of the present reserves of non-renewable energy sources of the world.

Distribution of coal reserves

Table 1 shows the distribution of coal reserves of the world among the continents [2]. The world consumes two or three milliards metric ton of coal at present. Consumption in the following thirty years will be five or ten times as much. Anyhow, the immense coal reserves of the world allow even such an unprecedented rate of development in mining and the explored reserves will last for many centuries.

At the present rate of consumption the estimate coal reserves in the world provide sufficient sources for 2000 years. This figure is 1000 years for Europe, 600—700 years for the United Kingdom, less than 200 years for France, 1000 years for West Germany, 2000 years for Poland.

It is a separate question that the distribution of the sources is extremely uneven and therefore necessitates reasonable international cooperation.

Table 1

Distribution of coal reserves of the world among the continents

Continents	Reserves (10^9 metric ton)	
	discovered	probable
Europe	548	1551
Asia	11	1097
Africa	9	206
North America	42	2115
South America	2	12
Australia	4	14

Distribution of crude oil reserves

Reserves of crude oil and natural gas are really giving out. Table 2 shows the reserves of crude oil in the world [2]. Experts in Western Europe estimate that the consequences will present themselves as early as the middle of the eighties. Problems are already showing up at the present, as we all experience.

Table 2

Distribution of crude oil reserves of the world among the continents

Continents	Reserves (10^9 metric ton)	Expected lifetime of reserves at the present rate of exploitation (year)
Europe	4.3	35
(the portion of Soviet Union)	(3.9)	(35)
Africa	0.5	–
North America	5.7	15
South America	3.3	18
Middle East	27.0	150
The Far East	1.5	60

It was not without reason what the American periodical "The Fortune" wrote already in 1972: "It must be admitted that the menaceful 'energy crisis' which is so widely discussed these days and may keep on to the end of the seventies is much more a consequence of certain causes and human problems than that of the running-out fuel reserves".

Therefore it has to be pointed out clearly that only cheap oil is meant here, that is, the reserves which can be exploited in the usual way. All oil reserves in the world are rather excessive. Let's think of the oil in the continental shelf, the oil mines hidden under seas and oceans, then of sticky oil and sand which consists of bitumen, and oil shale. These all will be utilized in due course, when cheap oil reserves will have given out and technological processes are adequately improved.

Oil production in the world will presumably be increasing up to the year 2000, then, reaching its culmination, it will slowly decline but hardly falls under the present level until the middle of the following century. During this period a considerable rise in the production and consumption of solid fuel may be expected. This form of energy will play an extremely important part. It is not merely the usual way of utilization, but also the new possibilities; for example using coal for the production of oil and gas, the technology of which is already known.

2.3. *Distribution of renewable energy sources*

Spatial distribution of hydraulic power reserves

Coming to the question of renewable energy sources, let's have a glance at Table 3 which shows hydraulic power reserves in the world. Reserves of water power of rivers cannot be estimated with certainty. Table 3 shows the

Table 3

Distribution of hydraulic power reserves of the world among the continents

Continents	Power (10^3 MW)	Production calculated (10^6 MWh)
Europe (except Soviet Union)	40	200
Asia (except Soviet Union)	58	290
Soviet Union	54	270
Africa	140	700
North America	50	250
South America	36	180
Australia	3	15
Total	381	1905

Table 4

Reserves of renewable energy sources of the world

Energy sources	Power (10^6 MW)
1. Solar energy	
(for heating and electric power)	170 000
2. Hidraulic power	
(for electric power)	
— rivers	0.381
— tidal power installation	1.0
— surface waves of oceans	57.0
— sea currents	0.1
	58.481
3. Wind energy	
4. Geothermal energy	
5. Oceanothermal energy	
6. Biomass energy	

distribution of power among the continents and the calculated production of energy for a period of duty of 5000 hours per year [2]. The distribution of potentialities is very uneven and the amount of total power is not very high either, if related to the balance of renewable energy sources as it is shown in Table 4. Utilization of these reserves also requires exceedingly high investment costs.

Reserves of renewable energy sources of the world

Table 4 shows a summary of renewable energy sources of the world [4]. It is, of course, solar energy which constitutes the greater part of renewable energy sources. Considering the absorption factor of the Earth which is 0.66 approximately, half of it can be utilized for supplying energy without upsetting the oecology of the Earth.

The relation of other renewable energy sources to the balance of the energy sources of the world is still difficult to evaluate.

3. Utilization of renewable Energy Sources

Now let's take a few interesting examples of the utilization of renewable energy sources.

3.1. *Utilization of Solar Energy*

As we have seen, solar radiation represents significant energy source having an intensity of approximately 1.3 kW/m^2 at the outer boundary of the atmosphere. On the surface of the Earth 0.7 kW/m^2 can be calculated as a maximum value. Solar cells convert approximately one tenth of that value directly into electricity. So even at the best, the surface of the solar elements in an electric power station of 100 MW would be 1.5 km^2.

Another example to evaluate solar energy: at the equatorial areas the solar energy falling to each cm^2 equals to 30 kg of oil per year. Even a 5% efficiency in its utilization is to be considered though investment costs are very high at present.

Utilization in sun-boylers

On the other hand, solar energy on the Earth can be utilized in sun-boylers where the temperature can reach more than 3000 °C. Such a sun-boyler operates among others in Montlouis, France. Figure 6 demonstrates one of the early implementation of sun-boylers made by Mouchot in Paris, at the end of the last century, for the World Exhibition in Paris in 1878. The analogy to

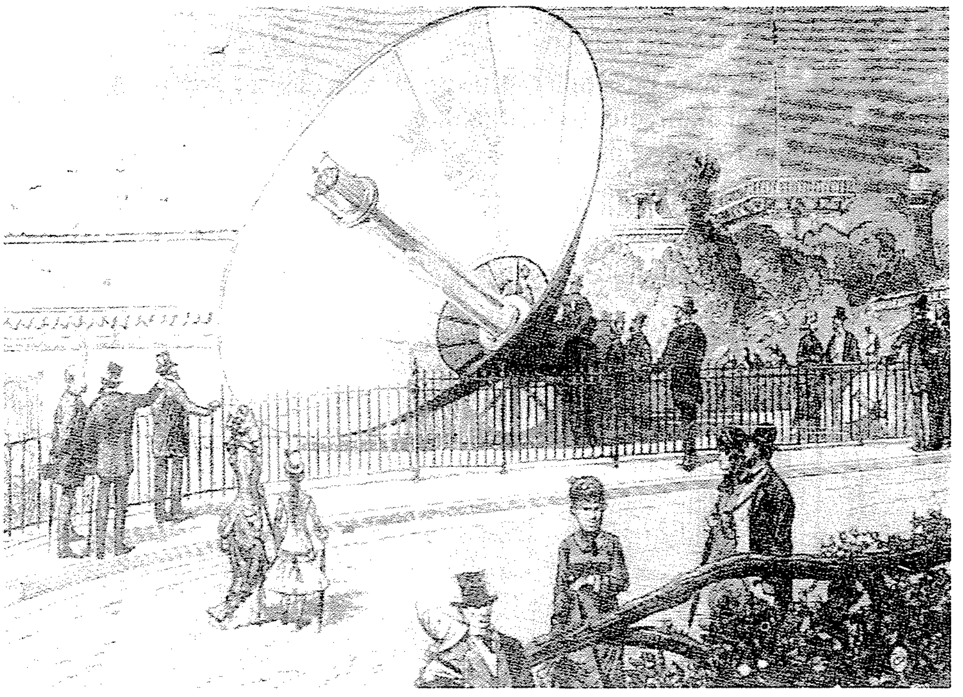

Fig. 6. Sun-boyler made by Mouchot in 1878

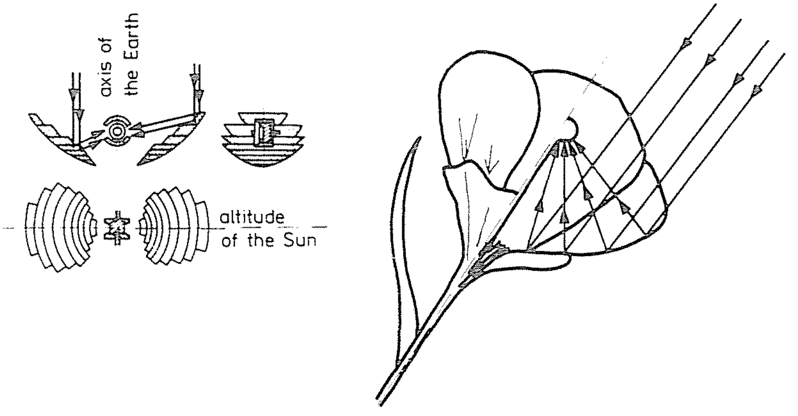

Fig. 7. "Heat-trap" of an arctic plant and a sun-boyler

Nature is surprising, as it can be seen in Fig. 7, where the "heat-trap" of an arctic plant is shown, aiming with its calyx at the low-rise solar orbit, the collected radiation warms the stigma over the environmental temperature [5]. On the left a scheme of a simple sun-boyler can be seen.

Direct use of solar radiation

A more promising possibility is the utilization of solar radiation as a heat source directly, or indirectly by the help of a heat pump.

Figure 8 shows direct use of solar radiation for the heating of water, partly for hot water supply and partly for heating swimming pools. From the solar

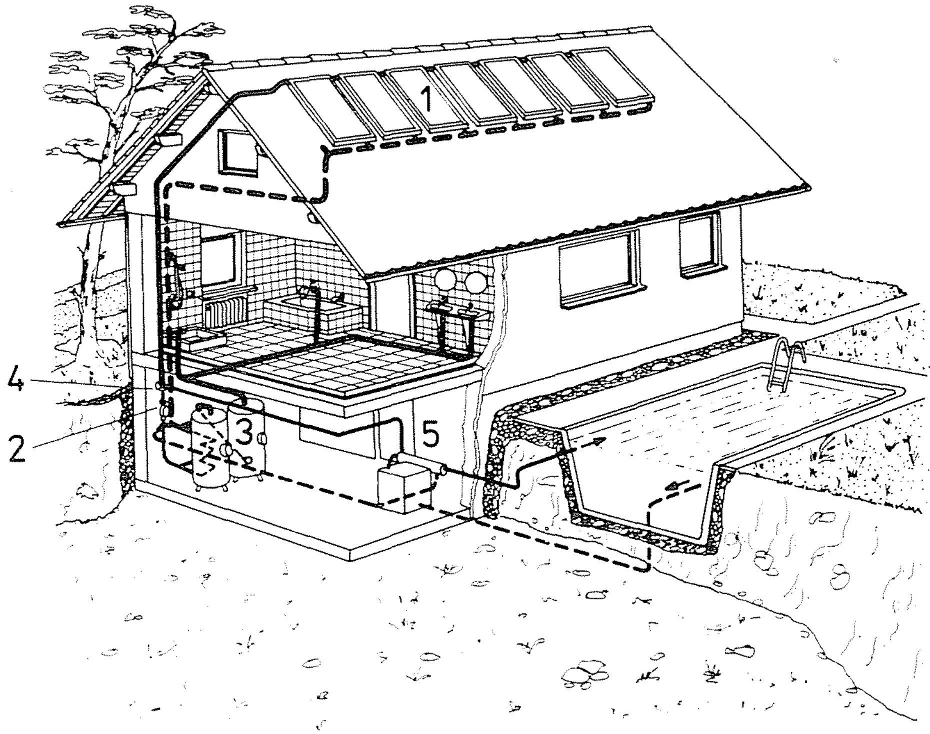

Fig. 8. Direct utilization of solar energy to hot water supply

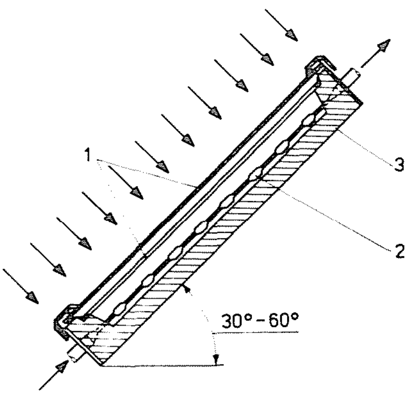

Fig. 9. Construction of a solar collector

collectors (1) the heat carrying agent transfers the heat through a feeding pump (2) to water heaters (3) or, after the suitable temperature is reached, the control valve (4) conducts the heat carrier to the heat exchanger (5) of the swimming pool [6].

Design of the solar collector is seen in Figure 9. The heat exchanger (2) with an absorbing surface is surrounded by thermal insulation (3) and sun rays arrive through the window pane (1) to the collector.

Utilization by the help of a heat pump

Figure 10 shows heating of a building, by mean of a solar collector (2) and a soil collector (1). The first collects sunshine, the latter geothermal energy. In both cases the building is heated by a heat pump (4) through radiators (5) or by floor heating (6). The control valve (3) provides a possibility to store solar heat through soil collectors also in the soil.

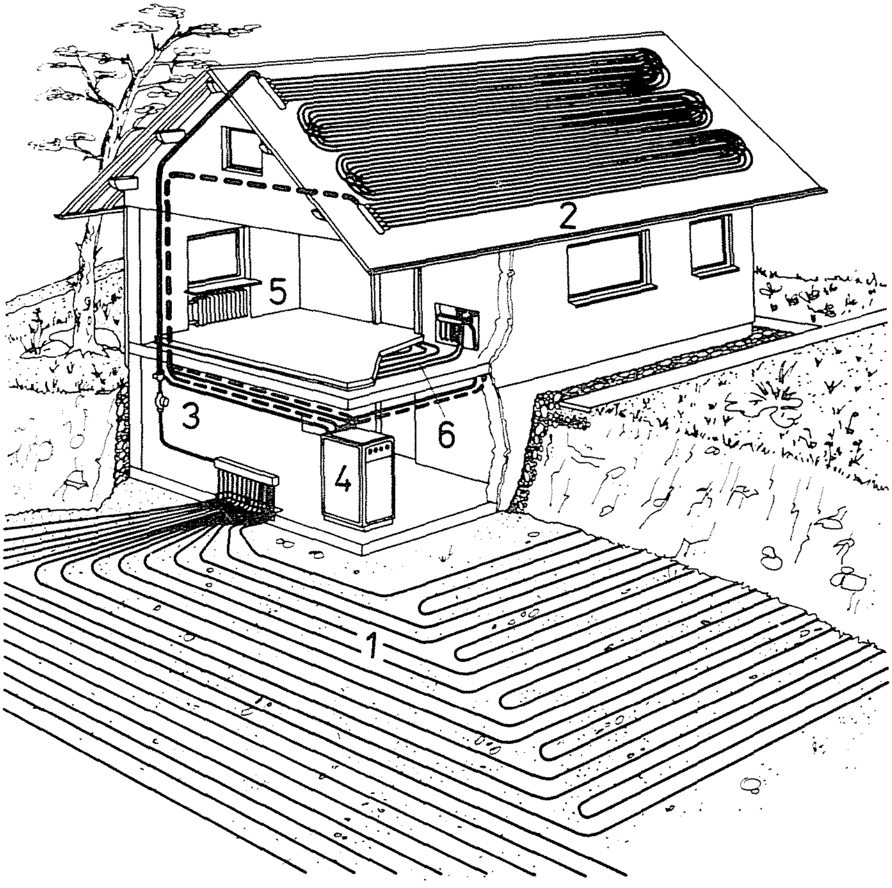

Fig. 10. Utilization of solar energy for heating with heat pumps

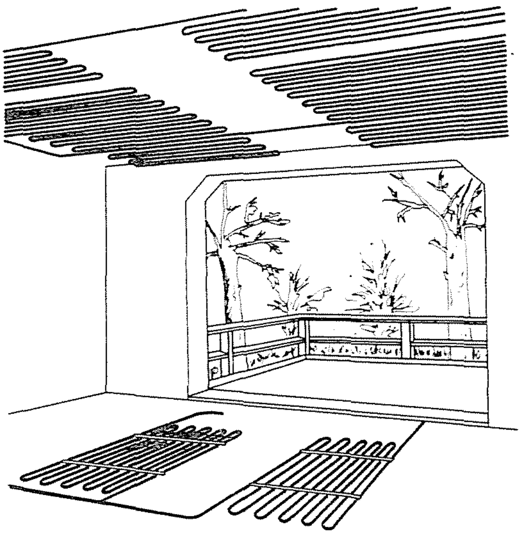

Fig. 11. Heating both in floor and ceiling

A heat-pump system like this is capable to raise the temperature of 1 m^3/h of heating water by 10 °C in case there is a 5 °C cooling in 1.4 m^3/h volume of groundwater and the rate of power input of the compressor is 3.5 kW. When combined with the sun collector, this can be sufficient [6].

When heating with solar heat instead of the traditional heaters, the heating coils are often placed into the walls. In Figure 11 both floor and ceiling heating is shown, incurring the possibility to use a heat carrier with a low temperature of 26 °C for the floor and 30 to 50 °C for the ceiling.

3.2. *Tidal energy*

The movement of more or less closed sea basins of a not too great deepness and the utilization of high and low tides are both known for quite a long time. In Bretagne, in France, many tide-mills were operated in the estuaries of rivers. For the utilization of tides the first industrial plan was developed by the French officer Belidor in 1737.

In contrast to the belief, energy dissipated by tides on the entire Earth is not very great: it is in the million MW order of magnitude (Table 4), i.e. of the same order than energy produced by man with power engines (in 1960 this amounts to 5 million MW). However, industrial use of this energy is only economical in places where the amplitude of tides is especially large and this is very rare. There is an operating power station near St. Malo, in France, where the tides, with an amplitude of 11.4 m drive an assembly of 24 units, with a

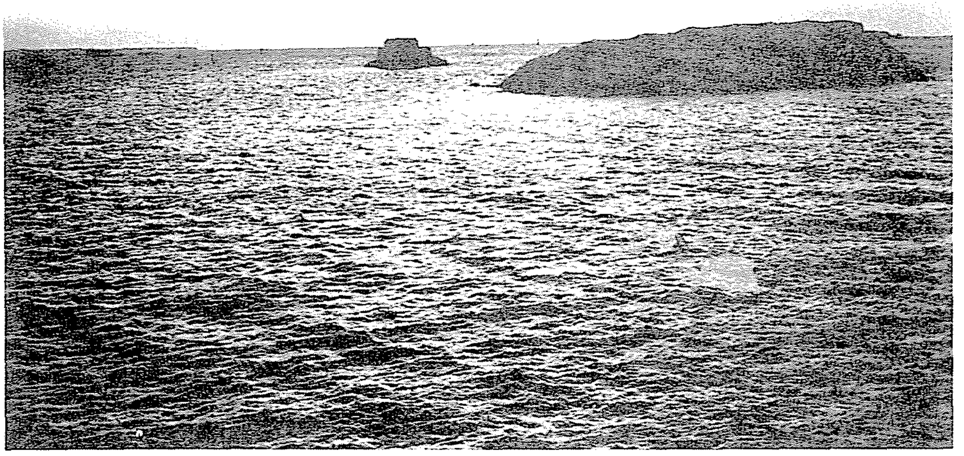

Fig. 12. High tide round the island "Grand Bé", in France, near the estuary of River Rance

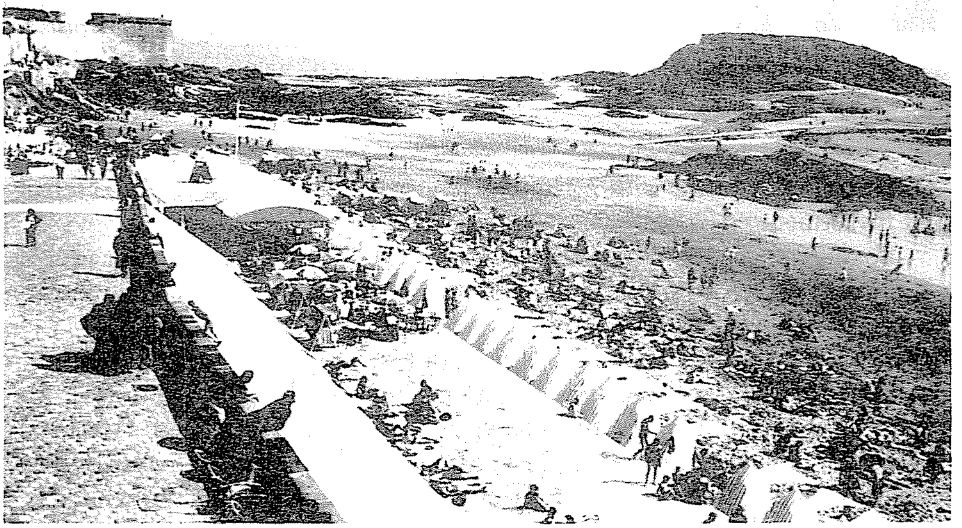

Fig. 13. Low tide round the "Grand Bé", where the tomb of the famous French writer Chateaubriand is

capacity of 10 MW each. Photos (Figs 12, 13 and 14), made during the construction of the power station illustrate the extent of the high and low tides and the dam closing the estuary of the river Rance, in which the water turbines have been placed.

At present few plans are known for further utilization of the tides: in Great Britain tides with an amplitude of 13.8 m, in the US with 6.6 m, in Canada with

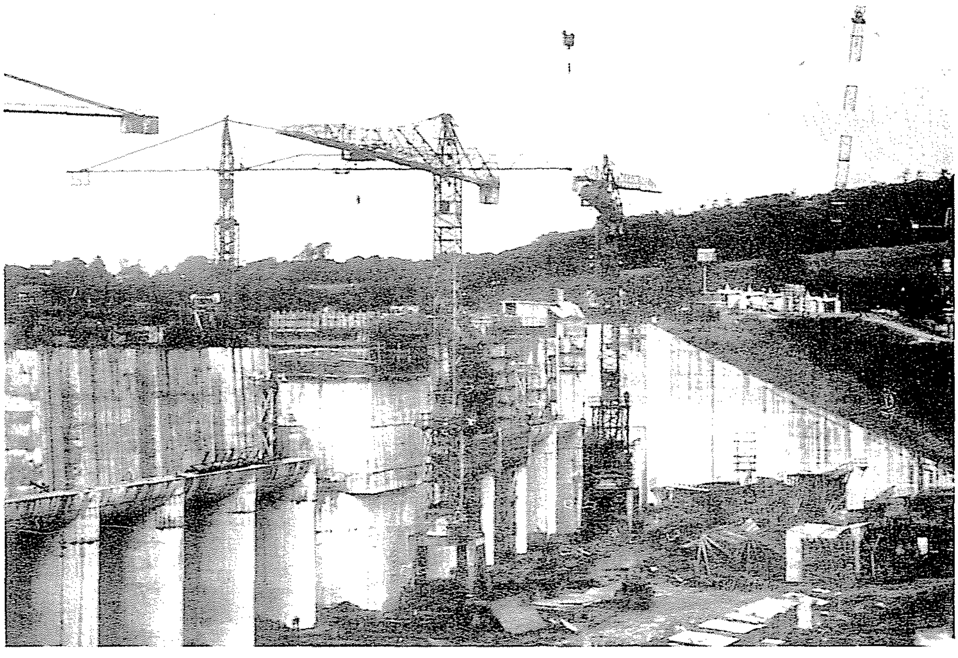

Fig. 14. Gates of water turbines in the barrage on the River Rance

12.7 m and in Argentine with 7.2 m. The realization is hindered by the extemely high investment costs.

Soviet calculations show that it is possible to get electric power up to a million MW order from tide waters along the European parts of the country. For ten years there has been a tidal power-plant with an output of 0.8 MW in the Kislaja Gulf in the Barents Sea north of Murmansk. Similar projects on much larger scales are planned, among others are those in Lumbovka and Mezen at the White Sea with a power output of 300 kW and 1300 MW, respectively. When completely developed, the Mezen plan will have an effect of 6000 MW, and included in the project is the building of a 50 km wide dam. Similar projects are considered near the power station on the River Rance, in France.

3.3. *Energy of currents and of the rolling sea*

Researchers were forced to use more unusual methods when attempting to reduce investment costs for sea energy utilization. Such is e.g. utilization of sea currents with the help of anchored boats, on which power could be produced by girating umbrellas, as shown in Figure 15. According to the American G. E. Steelman, even a mere 4% utilization of the Gulf Stream at Florida would give an 1 to 2 thousand MW output.

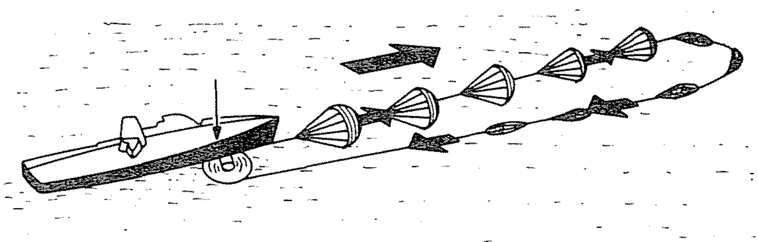

Fig. 15. Utilization of sea currents

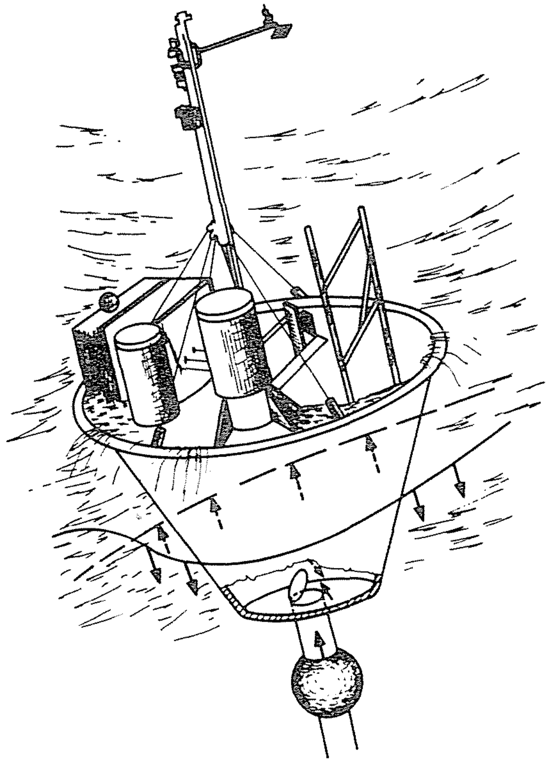

Fig. 16. Buoy using the transversal rolling of the sea

It is also the idea of an American, J. Isaacs, to utilize the transversal rolling of the sea, by means of buoys (Fig. 16), on the lower side of which a 100 m long synthetic pressure conduit produces a pressure of 20 bars, operating a turbine of 50 kW capacity.

In Great Britain longitudinal utilization of the surge of the waves has been developed. A plastic hose, divided into several chambers and filled with air is jointed with a suction and a pressure tube (Fig. 17). As an effect of the motion of

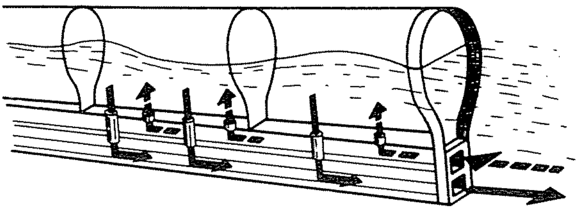

Fig. 17. Utilization of the surge of the waves

the waves, the air chambers are compressed and drive an air turbine. An air hose of 200 m length can give an output of 800 kW.

Other possibilities of renewable energy sources are still more difficult to evaluate.

The expression "against wind and tide" symbolizes the fight of man against the elements of Nature, but at the same time it also shows the way to possible energy sources.

3.4. *Aeolian energy*

It is true that wind mills are older than tide driven mills, but in the course of time they became more obsolete. At present there are also experiments under way to apply small wind power station, but their operation is only economical, where the winds tend to be rapid and frequent to contribute a complement to the power supply. That is the situation at sea-coast of arctic region where wind is continual and it has an average velocity of 22 km/h.

Figure 18 shows a West German wind power station with energy storage for feeding telecommunication equipment [7].

In Greece they are mainly interested in isolated installations with a power of 10 to 15 kW each, particularly to meet the needs of farmers in motive power. Due to the enormous increase in the cost of construction in relation to installed power, these small wind-motors constitute the ideal solution for the consumer living beyond the reach of the electricity distribution networks. Figure 19 shows a part of the plateau of Lassithion (in Crete) with the 10 000 windmills for pumping water [7].

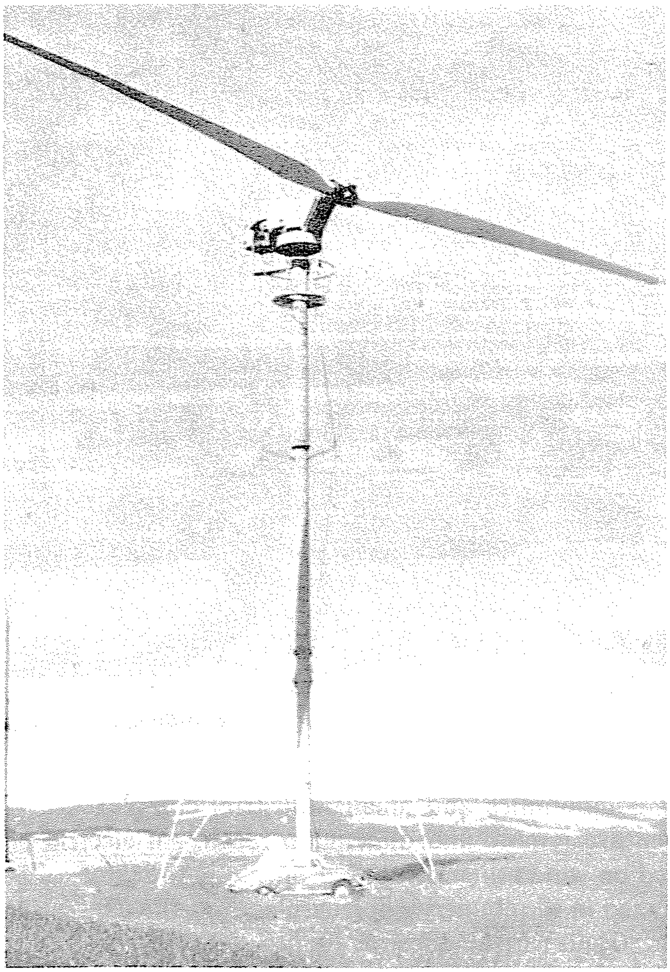

Fig. 18. Wind power station for feeding telecommunication equipment

In the Soviet Union at the present time a number of wind units with a power output from 1 kW up to 100 kW are tested. Testing areas for desalination are located in Moldavia and on the Caspian Sea. Both plants develop an electric power output of 4 kW and their capacity amounts to 150 500 kg/h de-salted water, respectively. The pumping and desalination of water is important especially in Central Asia where the only available source of water is salty sub-soil water. Experiments show that a wind unit of only 1.5 – 2 kW can supply 2000 sheep at water costs which are lower than if the water were pumped up by conventional, gasoline or dieseldriven units.

In addition to the wind power plants for a maximum of 100 kW, plants are well on the way for the construction of even larger units which are primarily

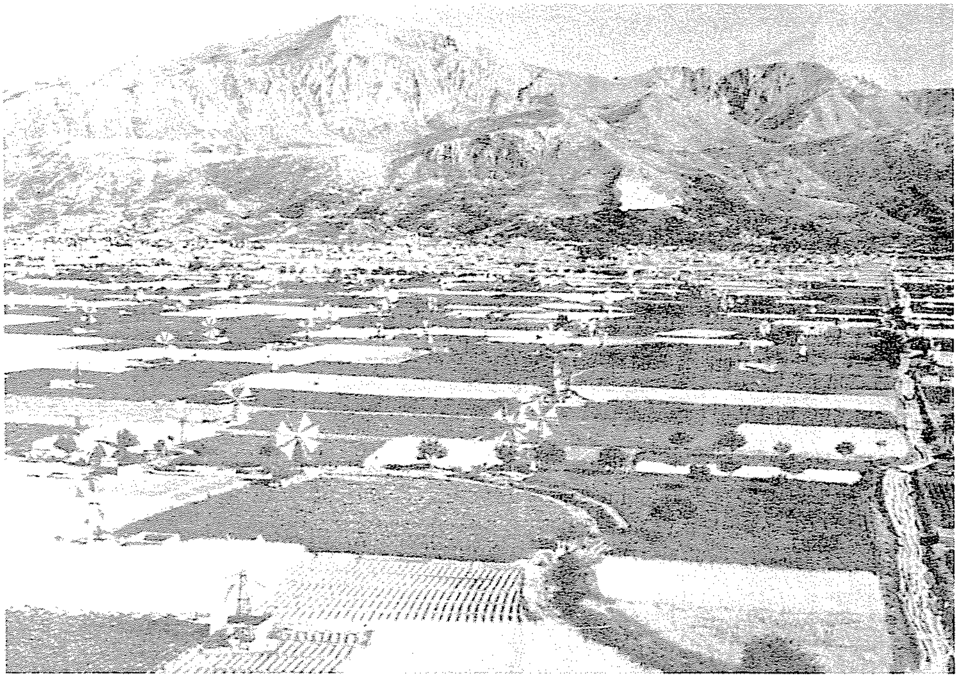

Fig. 19. A part of the plateau of Lassithion (in Crete) with the 10000 windmills for pumping water

intended for communities and small industrial complexes in parts of the country which are remote and difficult to reach. An electric power supply network based on wind units with power output in the range of 1 – 5 MW are to be constructed in the country's northern and north-east sections, ready for use around 1980 and with an effect of about 100 MW at the end of the 1980's. The production costs per kilowatt hour will be about 0.1 kopek/kWh for the northern windy regions, comparable to the costs per kWh for a large Soviet hydro-electric power station.

3.5. *Geothermal energy*

Utilization of geothermal energy may cover local power demands, specially where the geothermal gradient is higher than 1 K/30 – 35 m. An example of this is the power station with a capacity of 290 MW at Larderello, in Italy, utilizing the vapour breaking out of the earth, producing 2 million MWh energy per year, i.e. a tenth of the Italian power production.

Utilization of the Ocean's thermal energy is linked with the name of Georges Claude who pointed out at about 1930 that in the tropics the difference of the sea temperature, which is above 30 °C on the surface and 7 °C at a depth 5000 m, could be utilized. Among such circumstances the thermodynamic efficiency of the cycle is, of course, small (less than 10%), but the energy source is almost infinite. A pilot plant of France, in Abidjan (Ivory Coast), is operating on this principle.

By energy of the biomass methane is understood, which forms organic matters disintegrate under anaerobic conditions (fermentation); it can be utilized for the production of energy. There are but few examples for realization of it's industrial use.

4. Energy Supply Problem of Isolated Settlements

Finally, the energy supply of isolated special systems has to be mentioned which is also connected with the use of renewable energy sources.

Present trends show that the production and consumption have inevitably been separated geographically and the demands for power distributing mains and transmission lines have increased. However, the previous model of energy supply cannot be applied for the inhabitants of an island or an oasis.

On one hand, the sizes are too small to allow large-scale division of labour; on the other hand, due to natural factors, the possibility of joining to the transporting and energetic system of a larger unit is excluded.

At the present level of technical progress, the expansion of telecommunication systems also to these isolated settlements is possible relatively easily. Providing power supply is impossible any other way but for autonom sources of power. Solution of this kind also offers wide possibilities for engineering initiatives and imagination. A number of ancient, renewable sources of energy can be utilized at a higher level by means of today's technology. They will certainly be increasing both in number and in forms of solutions in the future, forming interesting energy alternatives for the solution of local problems of energy supply.

Summary

During the past two decades, man's requirements for fuel and other power significantly changed both by quantity and by structure. Two centuries ago, about 10% of utilized energy were non-renewable ones, as against the actual 90%.

During the centuries, the structure of energy utilization much changed throughout the world and also in Hungary, affecting utilization of renewable energy sources. Special energy sources and applications. World's renewable energy reserves.

Utilizations of solar energy: direct hot water production; applications combined with heat pump.

Possibilities and realizations of tidal power stations. Energies of currents and of the rolling sea and utilizations. Aeolian energy and utilization possibilities. Utilization of geothermal and ocean's thermal energies.

The role of renewable sources of energy for providing small isolated settlements.

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