The Impact of New Technologies on the Future Energy Supply

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INTRODUCTION

Two thirds of today's energy supply is provided by oil and natural gas, the resources of which are only on the order of 10 % of world fossil resources. The foreseeable depletion of the oil and gas resources, which as some recent studies (1,2) have pointed out may lead to a situation where supply cannot satisfy demand as soon as in the late eighties, requires a fundamental change of our energy supply pattern. In spite of the long lead times for the development and commercialisation of new energy technologies, one has to face the necessary transition today in order to avoid energy shortages in the future. The key technical issues lying ahead are the timely utilisation of new energy sources, the development of new technologies which increase the application and substitution potential of coal and nuclear energy, and last, but not least, to implement measures and technologies which make better use of the energy. In the industrialised countries, a broad spectrum of new energy production, conversion, transport, storage and end-use technologies is being developed. The most relevant of these technologies are described in this report and use the case of the Federal Republic of Germany in their present state of development; their supply and substitution potential and their economic aspects are discussed.

NEW ENERGY TECHNOLOGIES?

Let us start our discussion about new technologies by quoting the following: "Although energy engineering has progressed enormously, it will be necessary in the future to make other energy sources accessible and these will involve the use of solar heat, of wind, of tides and of the movement of sea waves."

This citation is not the recent statement of an energy economist or even the remark of a politician after the so-called oil crisis in 1973, but it stems from the 1905 Annual of Inventions – and, thus, was written about 75 years ago. It was our intension to place it in the beginning to point out that many of the so-called "new technologies" are not new at all.

Why then have common technologies such as biomass, wind, solar and tides, and even conservation, not dominated our energy system? One answer might be that there have been alternatives based on fossil fuels that have been cheaper. But prices for oil and gas have increased dramatically within recent years. Moreover, the expected depletion of these energy sources should lead to further price increases, and – which perhaps is still the more important – requires a completely new structure of energy supply. Now which role can so-called new energy technologies play here? Irrespective of what we mentioned in the beginning the term "new technologies" in a general way will reter to those technologies which play no role, or only an unimportant one, in the present energy supply.

Nuclear energy, one of the really new energy technologies, will be discussed only marginally here since it is a major subject of other presentations at this conference.

"New" energy technologies, as considered in the following, can be separated into three groups:

1. technologies that are developed for use of new energy sources,
2. technologies for a more efficient use of energy, and
3. technologies that make feasible new secondary energy systems or new conversion alternatives.

In Figure 1 the technologies for expanding our primary energy base are listed. They are of fundamental importance in the context of the exhaustion of the oil and gas resources, which supply 2/3 of our present needs. From today's knowledge they, and to a certain extent coal, will become the primary energy sources on which we have mainly to rely in the next century.

Apart from nuclear energy, which includes nuclear fission and nuclear fusion, this group comprises all technologies for direct and indirect use of solar energy, for example flat collectors or wind energy conversion systems, as well as technologies harnessing geothermal or tidal energy.

Technologies which emphasise the more efficient use of energy (see Figure 2) include those that reduce the useful energy demand by improvement of technological processes, such as better heat insulation in buildings, or techniques which improve the efficiency of energetic

technologies utilizing "new" primary energy sources	
nuclear	- LMFBR, HTR
	- fusion-reactor
solar	
direct	- solar flat collectors and absorbers
	- solar thermal power plants
	- solar cells
indirect	- wind energy conversion systems
	- ocean thermal energy converter
	- wave energy converter
	- ocean currents converter
	- biomass conversion systems
geo-thermal	- geothermal heat a power plants
tides	- tidal power plant

Fig. 1:

"new" technologies for efficient use of energy

- insulation techniques
- heat recovery
- coupled production of heat and electric power
- heat pumps

"new" secondary energy systems and conversion technologies

- coal gasification
- coal liquefaction
- hydrogen
- thermochemical energy systems
- combined cycle power plants
- fluidized bed combustion

Fig. 2:

conversion processes, such as the coupled production of heat and electricity, or the heat pump – just to mention two of many possibilities. The more efficient use of energy thus helps to reduce growth rates of primary energy consumption, thereby postponing the depletion of oil and gas resources. Apart from reducing environmental loads, the importance of such technologies stems from buying time for the transition from today's energy supply, based on oil and gas, to the new energy sources mentioned before, which are nearly unlimited in their potential supply.

The third and last group of new energy technologies (as can be seen from the lower part of Figure 2) comprises new conversion technologies. These include, for example, coal gasification and liquefaction or combined cycle power plants and new secondary energy systems such as hydrogen and thermochemical energy systems. The time available here, however, does not permit us to discuss in more detail all the new energy technologies mentioned. Let us, therefore, concentrate on the space heating sector which accounts for 40 % of the total final energy consumption and the new coal conversion technologies, which seem to have a high potential for direct substitution of oil and natural gas.

NEW SPACE HEATING TECHNOLOGIES

Figure 3 shows the use of energy in the domestic and commercial sector for the Federal Republic of Germany. Most of the final energy consumed in these two sectors was required in 1977 for low-temperature heat. The largest portion serves for room heating – about 82 % in private households and about 75 % in commercial sectors. When added to this, the energy consumed for warm water and process heat means that more than 90 % is used for low temperature applications.

These numbers impressively underscore the importance of room heating and, thereby, that of room heating technologies. Considering now that about 70 % of all the present heating systems use oil or gas, it is obvious that this sector offers major opportunities for conserving these two energy carriers which, in time, are going to become in short supply.

The so-called oil crisis in 1973 initiated enormous efforts for the development of new heating and cooling

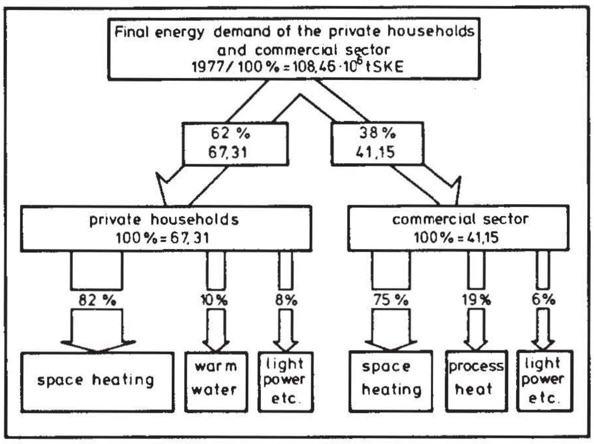

Fig. 3: Structure of the final energy demand in the private households and commercial sector

systems. In most countries main emphasis was placed on

- solar water and space heating systems,
- heat pumps, and
- combined power and heat production systems.

The technology for solar water and space heating is now commercially available in many countries. Dozens of prototypes and thousands of solar homes have been built or are under construction. For a climate typical of middle- and northern Europe, the systems for solar room heating are generally bivalent, which means they have a conventional back-up system to overcome periods of extreme coldness and periods without sunshine [3].

Figure 4 shows the fractional contribution of solar energy – that is the solar contribution of energy of the total demand for room heating – as a function of collector area and storage volume [4]. The results shown here refer to a single-family house for 4 persons with a living area of 160 m^2 and an annual heat demand of 28 MWh, the collectors being directed southwards with an inclination of 45°. Even when using the maximum area of 60 m^2 of roof collectors for this house and a storage volume of 200 m^3, which almost corresponds to the total volume of the basement, only 67 % of the heat demand will be covered by solar energy.

Today solar room heating systems with such large storage are still far from being economical. However, solar systems for warm water with a collector area of 6–8 m^2 could become economical in the next years, due to increasing energy prices. Besides these solar low-temperature collector systems, passive solar absorbers used in conjunction with heat pumps are becoming more and more important.

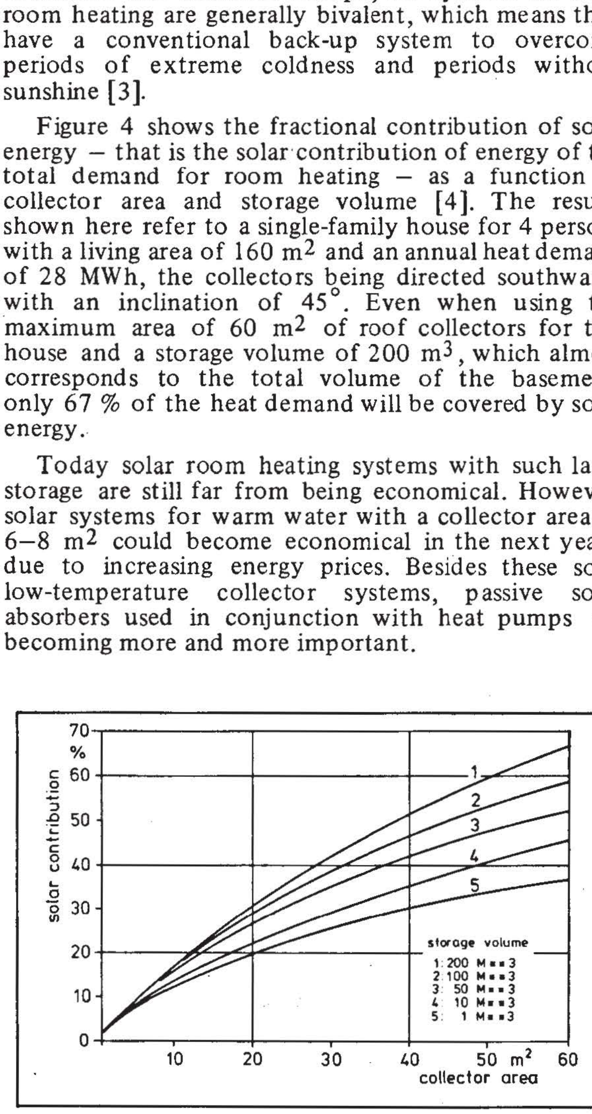

Fig. 4: Dependence of solar contribution on collector area and storage volume

Electrically driven heat pumps, which use environmental energy taken from air, water, or earth and designed for room heating and warm water, are commercially available today. Otto and diesel motors are being adapted to drive heat pumps for the required lifetime. For compression heat pumps, rated up to some hundred kW of driving power, one prefers piston compressors, whereas for the power region beyond that one applies turbo compressors. About 4000 heat pump systems were installed in the Federal Republic of Germany by the beginning of 1978.

District heating using fossil fuels is already used in about ten west European and in most east European countries. The price increase of oil and gas which has taken place has stimulated great interest in a wider use of district heating, which would have a tremendous impact on the environment and fuel conservation when produced in combined heat and power plants. Besides the further development of large scale centralised district heating systems, including nuclear district heating, considerable efforts have been devoted to the development of small scale so-called block heating systems. Although their technology has long been known, block heat power stations have been installed only in the course of recent years, usually employing diesel motors and ranging in power from some 100 kW's up to some MW's. Decentralised block heat power stations are economically competitive today. They can be viewed as an ideal first step for an integrated district heating system.

Let us now compare the cost and efficiency of different heating systems.

In the upper part of Figure 5 a comparison is shown between heating costs of the new room heating systems, as already discussed, and the oil and gas boiler system which dominates today. In addition, the electric heating system for evernight storage is shown. Relative costs are plotted for 1979 and 1990, each referring to those for oil burner heating costs in 1979. Heating systems presently most favourable in cost are those for gas boiler heating and district heating. This is the case for district heating only with consumer densities of more than 30 MW/km^2. The latest price increase for fuel oil has raised their cost to those for overnight storage heating. Although, as mentioned before, the combined production of power and heat is economical today for high density areas, the costs for heat pumps and solar energy systems are considerably higher than those for oil burner heating. This runs up to 25 % with the monovalent electric heat pump, 40 % with the gas heat pump and 230 % with the solar energy system. Assuming a nominal fuel price increase of 9 % a for oil, 7 %/a for gas and 4 %/a each for electricity and district heat, the cost for gas heating and overnight storage heating will nearly equal that of electric heat pumps in 1990. Under these assumptions, oil burners clearly come out more expensive than heat pumps, but still they are more economical by one third than solar heating systems.

Regarding the lower half of Figure 5, a comparison of the efficiency rates of primary energy for different systems is given. All new technologies are clearly more favourable. In the case of district heating, for example, the primary energy required for production of one unit of useful heat is only about 30 % as high as that of oil heating. Gas heat pump and solar energy heating need about half as much primary energy, while the electric heat pumps are more favourable than oil heating by only about 30 %. As expected, the worst place in this comparison goes to direct electric heating, the primary energy consumption of which is about twice as much as that of oil heating.

Summing up the results of Figure 5, one can easily recognise that district heat is already economical if the consumption densities are high. Heat pumps might become economically competitive in the near future, but even with considerable price increases of oil, solar heat systems will probably reach the economic border only around the end of this century.

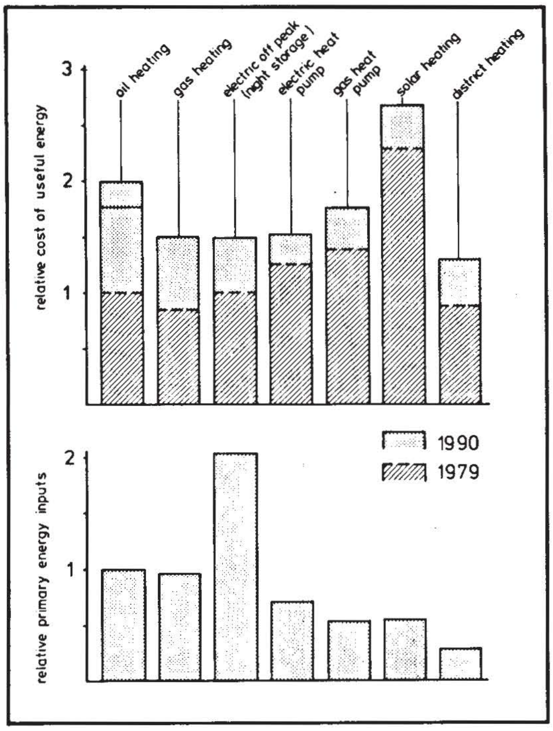

Fig. 5: Comparison of cost and efficiencies for heating systems

COAL CONVERSION TECHNOLOGIES

The interest in a greater use of coal which has been lately shown in some countries, is, on the one hand, due to the sharp rise of the price of oil and, on the other hand, a political decision to obtain a secure energy supply by using domestic coal, which is available in huge amounts in some countries.

For coal to be able to make its full contribution to future energy supplies, new coal combustion and conversion processes must be developed.

In Figure 6 the most important possibilities are shown for the conversion of coal into different energy products. Today, coal, besides its use as coke in the iron and steel industray, is nearly exclusively converted into electricity, district heat and space or process heat by direct combustion. At present the main efforts to improve coal combustion are directed to the development of the fluidised bed technique which seems to have a broad range of application and economical, as well as environmental, advantages compared with today's coal burners.

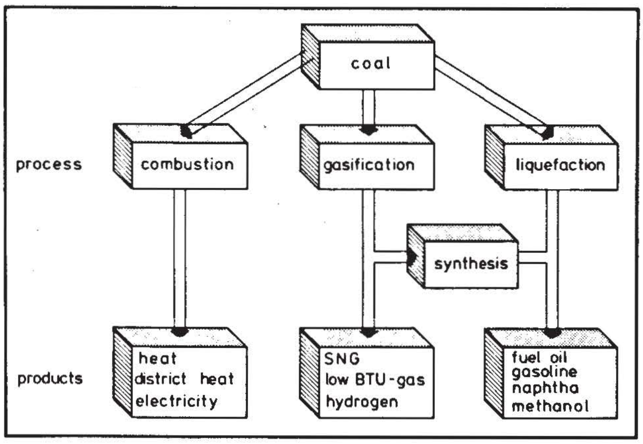

Fig. 6: Coal conversion possibilities

The possibilities for coal to become a real substitute for crude oil and natural gas seem to be limited via the combustion route. Coal must be converted into clean liquid and gaseous fuels to allow direct substitution of gas and oil products in the different end use sectors and to be used as chemical feedstock. In this context, it is appropriate to consider coal as a hydrocarbon compound which, compared with oil and natural gas, has a deficiency of hydrogen. The conversion of coal into clean liquid or gaseous hydrocarbon fuels therefore requires the addition of hydrogen. Thus a broad spectrum of hydrocarbons ca be produced by gasi fication, liquefaction or one of the synthesis processes following gasification. The latter range from SNG via synthesis gas, through fuel oil, gasoline, naphtha and methanol.

The fundamentals of the coal gasification and liquefaction processes known today were already developed several decades ago. During World War II the hydrogenation plant capacity in Germany amounted to 4.3 million tonnes/annum and the capacity of the Fischer-Tropsch plant to 0.7 million tonnes/annum.

Although coal gasification and liquefaction are familiar processes, there has been renewed effort in recent years on the further deveopment of known processes as well as the development of new ones. In the forefront of requirements we have, besides economic improvement, the widening range of applications raising the conversion efficiency and meeting environmental standards.

Here we cannot go into detail on the individual processes which are under development for coal gasification and liquefaction but let us say a few words about gasification in combination with nuclear heat.

As an example, Figure 7 shows the general scheme of the hydrogasification of brown coal to SNG with nuclear heat. Raw brown coal is fed into the gasifier in which it is gasified with hydrogen in an exothermic reaction in a fluidised bed at 850 °C and 80 bar. After passing through the gas cleaning stage the raw gas is separated into methane and hydrogen. The hydrogen is recycled to the gasification reactor. A fraction of the methane, the product gas, is fed into the steam reformer and converted to carbon monoxide and hydrogen so as to meet the entire demand for hydrogen. Heat on a temperature level of about 800 °C is required for the reforming of methane. This heat is supplied by a high temperature reactor.

The main advantages, and thus the motives, for nuclear coal gasification are the roughly 40 % lower coal requirement compared to the conventional process and a relative reduction in the cost of products due to the application of cheap heat from the nuclear plant.

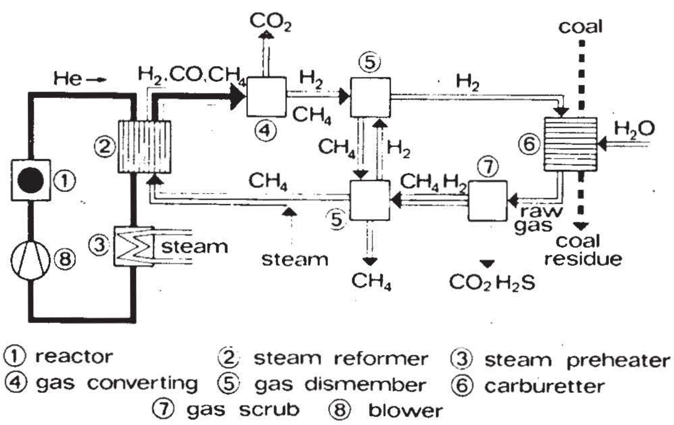

Fig. 7: Hydrogasification of brown coal to SNG with nuclear heat

Apart from the technical problems still to be solved, the high cost of the liquid and gaseous products of coal conversion remains a barrier to the large scale introduction of both types of processes.

The production costs of SNG from various gasification processes as a function of the cost of coal are shown in Figure 8 [5]. With a brown coal cost of 8 DM/Gcal the SNG cost with nuclear gasification is 30 DM/Gcal and with autothermal Winkler gasification 32 DM/Gcal. These costs are over 50 % higher than the price of natural gas today. However, it is expected that due to the rising prices of natural gas, the gasification of brown coal will become economically competitive in the near future. The future situation of SNG produced from domestic hard coal is less promising due to the high price of 22 DM/Gcal of coal in our country.

SNG produced from hard coal will cost approximately 40 DM/Gcal in the case of nuclear gasification and possibly as much as 55 to 60 DM/Gcal with the autothermal Lurgi process. Higher costs of coal bring out clearly the economical advantages of nuclear versus autothermal gasification.

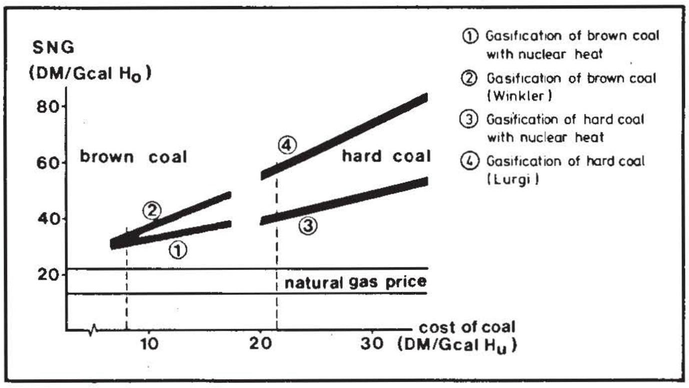

Fig. 8: SNG-production cost vs. coal cost

CONTRIBUTION OF NEW TECHNOLOGIES TO FUTURE ENERGY SUPPLY

Having described some of the so-called "new" energy technologies we would like to turn to the question of what contribution these new technologies can make to the future energy supply. The following statements should not be taken as predictions but rather as an upper estimate of the contribution of new energy technologies on the assumption of optimistic, but not unrealistic, possible introduction dates and market penetration rates.

Figure 9 shows a scenario of the development of final energy demand and its structure in terms of energy carriers for the Federal Republic of Germany. Based on assumptions of future slowing economic growth and enhanced introduction of measures for a more rational use of energy, the final energy demand increases from today's value of 250 mtce to only about 390 mtce in the year 2000.

On the assumption of continued rising oil and natural gas prices, heat pumps and later also solar warm water and heating equipment come into the market. With optimistic assumptions about the rate of introduction, both systems together could be saving about 25 mtce of final energy by the year 2000. About 3 mtce of this is due to the much smaller share of solar systems, of which about 3.5 million would need to be installed by the year 2000, comprising a total collector area of about 64 million m^2.

Regarding the contribution of synthetic hydrocarbons it is assumed that conventional coal gasification plants are commercially available in the middle eighties,

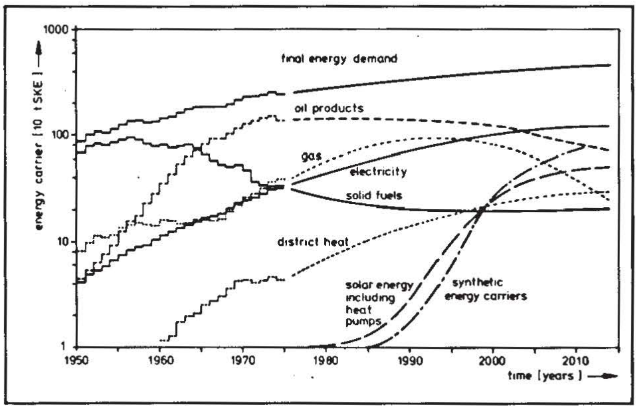

Fig. 9; Development of final energy carriers in the Federal Republic of Germany

liquefaction plants in the late eighties and nuclear coal conversion processes in the middle nineties. From these assumptions about 25 mtce of synthetic fuels could be produced in the year 2000. This is of the same order as the potential contribution of heat pumps and solar systems.

Let us again emphasise that these figures are an upper limit and that they are to be achieved only under most favourable circumstances.

CONCLUSIONS

The future depletion of the oil and gas resources, which, as some recent studies have pointed out, may lead to a situation where supply cannot satisfy demand as soon as in the late eighties, requires a fundamental change of our energy supply pattern. In spite of the long lead times for the development and commercialisation of new energy technologies, one has to face the necessary transition today in order to avoid energy shortages in the future. The so-called "new" energy technologies like heat pumps, solar systems, wind converters, coupled production of heat and electricity, coal liquefaction and gasification, to name only the most important of them, can make a moderate contribution to the energy supply in the year 2000, which might be of the order of 20 % of the final energy demand. The uncertainties underlying this estimate are great, but on the other hand the uncertainties surrounding the future development of energy demand and supply make it imperative that we develop in parallel a multiplicity of options and energy technologies.

Such a policy might create for us the future freedom of choice, when the open road – today hidden in fog – is more clearly visible.

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