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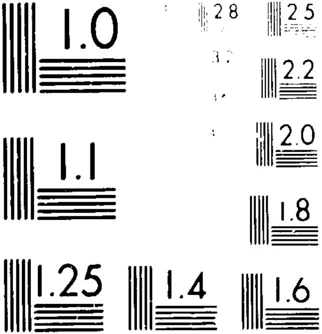
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→ Maria Dietrich

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WORLD ENERGY PROBLEM

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I. INTRODUCTION

An assessment of the world energy situation as it exists today and as it is likely to develop in future represents a constant interest of responsible national and international bodies and serves as an everlasting theme of discussions and polemics. At the end of all these there remains one question expressing common deep uneasiness: "Could we satisfy the steadily rising energy demand"?

In the present paper let us deal with present state of energy situation and its future prospects.

II. CURRENT WORLD ENERGY SITUATION

Energy production and consumption

According to the UNO statistics the total production of energy in the world in 1975 was about 245 Exajoules ($1 EJ = 10^{18} J = 34.13 \times 10^{6}$ tons of coal equivalent $= 238,85 \times 10^{12}$ kcal)

The overall consumption of the primary energy resources has developed recently in a somewhat peculiar way. As can be seen on table 1 [1], the overall world consumption of the primary energy resources has risen from 94 EJ in the year 1955 up to 244 EJ in 1975, e.g. by a factor of 2,59 within 20 years, average growth 4.9% per year. Till 1970 this percentage of growth was even higher - about 5.1%, whereas it dropped recently to the annual 4.2%. This drop was caused by the big oil price increases as well as the price increase of other primary energy resources throughout the mentioned years. The primary energy consumption in 1955 to 1975 period is characterised by rather a modest growth factor of 1.48 in coal consumption, whereas oil consumption has risen 3.93 times and that of natural gas even as much as 4.15 times. Thus the oil and natural gas covered in 1955 about 41.9%, in 1975 already 64.8% of the overall energy balance. Hydroelectric power plants and nuclear power plants achieved a growth factor of 4.6 (mainly due to nuclear power growth) but their total absolute asset is still only modest.

Throughout the 1955 - 1975 period the world population grew from 2.71 billion to 4.04 billion, e.g. 1.49 times making an average annual growth rate of nearly 2%. Per capita primary energy annual consumption in the mentioned period rose from 34.81 GJ to 60.34 GJ. This specific primary energy consumption corresponds with the overall level of national economy in individual countries. A tremendous difference between economically fully developed industrialised countries and developing countries exists, which is illustrated by a table 2 where specific primary energy consumption in 1975 for various countries is quoted.

Even if we do not consider the case of Quatar (relatively high energy consumption in the oil fields and very low population) in the economically developed countries spend more than 80% of the world's energy resources, whereas the rest of the population (e.g. 75% of it) consume only mere 20% of energy resources. This is not only an economical but a primary political problem as well.

In this context let us consider the question, whether this high average energy consumption is a necessity and how mankind in previous centuries managed. In times before industrial revolution most of the energy consumed was produced by man himself or animal. What amount of energy was available here? Let us make the following approximate consideration [2]: In Roman Empire the population on the Appenine peninsula was about 20 million of the citizens of Rome with about 120 million of slaves at their disposal. Assuming man can develop continuously 0.1 horsepower e.g. 0,06 kWh, then at 8 hours daily work one slave was worth about 0.6 GJ annually, and for 6 slaves toiling for one Roman citizen we get an annual energy consumption per capita of about 3.6 GJ. This figure is in the order of magnitude of the contemporary per capita annual energy consumption of India or Bangladesh (see table 3).

If we transform the figures of table 2 into the hypothetical "Energy Slaves", we get for various countries the number of "Energy Slaves" available for each inhabitant - see table 3. These figures probably more aptly illustrate not only the huge increase of energy consumption since the first centuries of our era, but the difference between the industrialised and developing countries nowadays.

III. FUTURE PROSPECTS OF THE ENERGY CONSUMPTION

Future development of energy consumption will be subject to two contradictory trends

- the growth of energy consumption
- the reduction of energy consumption, energy conservation or only a modest rise in energy consumption.

Energy consumption growth

Further growth of the energy consumption in the world is expected as can be seen from the table 4 [3]based on the estimates made by the UN Statistical Office, New York.

The present distribution of commercial energy consumption reflected in Table 5 shows the total and per capita energy consumption in industrialised and developing countries and their striking disparities. The average per capita consumption in industrial countries is more than 8 times larger than that of developing nations. To this disparity corresponds a similar gap in the standards of living which can only be reduced by economic and industrial development. This process of development will necessarily involve rapid growth of commercial energy demand since the initial stages of industrialisation are particularly energy intensive. Thus, even if by intensive conservation and restrictive policies, the industrialised nations were to maintain zero energy growth, the pressure of demand from developing countries would bring about a substantial increase in world energy needs.

However, zero energy growth in the industrial countries is an illusion, at least over the short term, because most of the measures designed to achieve the greater economy in energy use require long periods of time to achieve their full impact. Consequently the growth of energy demand can be expected to continue in industrialised countries although it will proceed at rates substantially lower than those which prevailed during the last 30 years.

Further, mankind is progressively exhausting its best deposits of mineral ores and as it turns to ever lower grades of minerals or to the recycling of various metals, the demand for energy in the mining industries is likely to increase progressively.

Finally, measures to protect the natural environment (air and water pollution problems, desulphurisation of fuel or fumes etc.) are very energy demanding too.

Energy conservation

Essentially there are three ways of conserving energy:

- by not doing things: no heating, no travelling
- by reducing the quality: heating to lower temperature, travelling in smaller cars at a lower speed
- by retaining the standard but using less energy through improved efficiency:
  domestic insulation, more efficient cars and engines, better energy management.

The first two options can be enforced quickly in case of national emergency, but neither can be expected to be widely accepted over a long period. The third option would require substantial initial capital expenditure - not only by the industrial, commercial and public sectors which are used to make and evaluate investments, but also by individuals. Nevertheless, this course, once started, does not require continued austerity, and, is therefore likely to be the most effective in the long term.

It is important to realize that energy efficiency has been improving for many years. Some of the most important measures in energy conservation are listed in a Table 5 [4].

Fig. 1 [4] indicates the contribution that improvements in energy-use efficiency could make to reducing energy demand (or rather, to reducing the growth in energy demand). This figure summarizes for Western Europe a detailed estimate by sector and country of the amount of total primary energy that would have been consumed in 1975 if all the energy-consuming equipment were of the standard of efficiency appropriate for the energy prices then prevailing. This hypothetical example shows clearly that the potential saving is indeed significant. 13,7 EJ/a (about 325 million tonnes a year oil equivalent) which represents over 12% of the oil consumed that year on the whole world. Energy saving estimates for industry in W. Europe [4] show, that based on 1973 practice some 15 to 30% can be saved in 2000 in energy intensive industries (e.g. iron steel and other furnace exploiting industries).

The problem with all energy conservation measures lies in the time span: truly massive employement of them could be realised and may bring significant effects within 10 years in transport, not sooner than 20 years in industry and well over 20 years in heat delivery field. Most individuals and companies allow substantial shorter time for their investments to be paid back; there remains then the task of lengsthening the time horizon for both individuals and organisations to accept and actively apply conservation of energy.

IV. PRIMARY ENERGY SUPPLIES

As we have just seen the energy consumption will continue to grow, and the effect of conservation measures though significant later will not reverse this trend. What then are the potential sources of supply on which mankind can draw to meet rather conservative estimate of an approximate doubling of demand over the next two decades? Taking Table 4 as a basis (Estimates in it were prepared by the UN Statistical Office, New York) the cumulative energy consumption of the world over the next 20 years would be of the order of 10500 EJ. Should oil retain its share of the market (see Table 1) it would require a cumulative production of more than 4700 EJ (e.g. more than 110 billion tons of oil equivalent) against proven reserves of about 3800 EJ (e.g. 90 billion tons).

On a Table 6 [2] we can see the expected development of various energy resources up to the year 2020. Figure 2 shows us very clearly the proportion of various primary energy resources throughout this century and further on to 2020.

Of course, more reserves probably might be found at ever increasing costs but these new discoveries could only postpone by a few decades the unavoidable ultimate exhaustion. A similar situation prevails for natural gas. Thus, the two energy sources which account for close to two - thirds of the world supply today are going to become increasingly scarce in the immediate future.

While resources of coal probably exceed those of oil and gas by an order of magnitude, they share with hydrocarbons the serious shortcoming of a highly uneven distribution among the various countries of the world. In addition, a rapid expansion of coal production would give rise to serious environmental and social problems so that it can only partially fill the increasing gap which the progressive depletion of oil and gas reserves will leave open.

Finally, renewable sources of energy must be developed at maximum speed wherever conditions warrant, but these resources are either already heavily exploited and locally bound, as in the case of hydroelectricity, or available in such diluted and irregular forms, as in the case of solar and wind energy, that they offer only partial and limited solutions to the general energy problem. Their combined share of world supply therefore is unlikely to exceed 10% of the total by the year 2000.

On the other hand, nuclear power appears technologically and commercially ripe for an immediate and expanding contribution.

V. FUTURE PROSPECTS OF NUCLEAR POWER

Without going into complex comparative analyses of electricity generation costs, which depend on the ground rules chosen nad will therefore vary widely from country to country, the following major points may be made:

1) In spite of the sharp increases in the investment costs of both nuclear and conventional power plants which have taken place over the last few years, usually as a result of numerous and very strict environmental standards, nuclear power plants of 900 MWe and above have a clear competitive advantage over electric stations depending on imported oil.

2) The situation at competition between nuclear and coal fired plants is more complex and depends on the production and transportation costs. However, for a majority of industrial countries, nuclear stations continue to show an economic advantage in large sizes even at relatively low coal prices.

3) As to the future, it seems very likely that both oil and coal prices will increase faster than those of uranium and of nuclear fuel services.

As for nuclear fuel resources there are at present 2 million tons reasonably assured and another 2 million tons of estimated additional reserves, which covers the needs of the maximum nuclear power programmes up to the year 2000. Of course, new discoveries are essential for maintaining forward reserves and meeting the lifetime requirements of all those nuclear power plants which will be operating beyond the turn of the century. The first results of a new prospecting efforts are already encouraging.

Regarding the other sectors of the nuclear fuel cycle, neither the cost of enrichment, nor that of fabrication are expected to rise faster than the general price level of industrial goods.

There are the first favourable results with the fast breeding reactors in the USSR, in France and elsewhere which will provide a solid foundation for a nuclear sector, whose fuel resources would become practically unlimited. This would result from both a hundredfold increase in the energy which could be derived from known uranium resources, and the economic possibility of mining much poorer uranium ores.

By the end of the century nuclear power is expected to account for 26 to 35% of total electricity production and for 12 to 16% of total primary energy. While these objective may appear relatively modest in comparison with earlier expectations, their achievement would nevertheless bring about a substantial alleviation of pressure on hydrocarbon resources. Production of nuclear electricity at these levels would represent the equivalent of 1.5 to 2.4 billion ton of oil, as compared to a 1978 world oil production of about 3 billion tons.

VI. NUCLEAR ENERGY AND ITS WIDER APPLICATIONS

In order to develop into a long term and large scale supply option, nuclear energy has to meet further requirements.

So far it has been primarily considered a technology for electricity production. The proportion of electricity on the energy consumption balance in industrial countries reaches nowadays about 20 to 25%. This proportion will grow further, but still there is a vast field of demand for energy in other modes. (See Table 7)

Heat delivery for district heating purposes and low potential technological heat for industry will certainly be realised by dual purpose nuclear plants designed for combined heat and power production. It is expected, that all of the newly built nuclear power plants in Czechoslovakia will be designed with the prospect of district heating heat delivery up to the distance of 50 kilometres from the plant. No doubt similar decisions are being taken elsewhere, where the meteorologic conditions, the plant location and safety considerations permit. As for the low potential heat for technological processes, nuclear power plants now designed could be equipped with steam transformers or intermediate cycle arrangement capable of saturated steam delivery in the wide range of pressures up to 3.5 to 4.0 MPa (about 242 to 250°C).

There still remains a wide variety of applications in chemical, metalurgical, ceramic and other industries, and in transport where energy demand can be fulfilled neither by electricity nor by the relatively low potential heat from present day prevailing type of lightwater reactors.

These needs at present are satisfied by winning the heat directly by burning fosill fuels. Ultimately, fossil fuels (oil, natural gas, later even coal) will be in short supply and the world must turn to other basic energy sources and seek other means to carry energy to end-use. From many candidates prepared to assume this role (hydrazin, metanol, ammonia, etc.) hydrogen seems most suitable energy carrier. Like electricity, it is not a naturally occuring energy form, but must be manufactured. It can be produced from water, could be easily transported and stored.

It applicability is manifold: in chemical industry, metalurgical industry (direct metal reduction), in transport as a fuel, in heat production (catalytic combustion), even in electricity production (fuel cells, gas turbines). All forms of hydrogen uses lead back to water formation which returns into the natural cycle. In the hydrogen energy system water represents main abundant raw material and hydrogen the "clean" energy medium, which presents no problem from the ecology point of view.

At present, electrolysis of water seems to be the principal means of hydrogen production. This is not a particularly cheap way of hydrogen production (due to the relatively low efficiency of electric - generation step, most commercial electrolyzers work nowadays with the electricity - to - hydrogen efficiency of 75%), but with scarcely any other alternative left world must cope with this. Even here there is a "silver linen" to this cloud: nuclear electricity used for hydrogen production could be taken mostly at night or weekends thus helping the nuclear power plants to generate electricity at base load all the time. The base - load operation of the nuclear power plant is advantageous from the points of view of nuclear fuel economy, and reliability.

There is still one source in the sphere of electric production heat delivery for district heating and process heat for industry. It is the high temperature gas cooled reactor (HTGR). Their advantages are in higher cycle efficiency, potential to use a closed cycle gas turbine with attractive investment costs and high temperature process heat applications (see Table 7). The first demonstration power plants of this type are already in operation for some years, big commercial units are expected before the end of this century.

VII. CONCLUSIONS

As we have seen already, the world is going to require more energy in general, and more electric power in particular. At the moment there is no marked shortage in electric power yet, there are still various primary energy sources at our disposal. The problem lies ahead of us, and how big it is depends on the future development of economic growth and power demand. Some assumptions on this are presented in this paper, lot of different numbers could be found elsewhere. There seems to be, however, general agreement on the coming shortage in traditional primary energy sources.

Practically, the options for future come down to coal and nuclear power. Solar energy and some of the other unconventional technologies are not going to give us significant growth in the electricity generation in the rest of this century. Aside from the fact that coal has some problems and side effects such as ever rising costs of mining and transportation, environmental and health loads, there is evergrowing demand for coal as a material for synthetic fuel and other chemical industries' products.

At the beginning of 1980 there were about 120 000 MWe of nuclear power in operation and further 340 000 MWe in construction and planned; practically, nuclear power plants remain as the readily available already proven source of power. They do not represent such environmental problem as coal firing plants, they save oil and gas. Their cost of kilovatt hour is at least competitive and tends to be lower than power from coal (not to speak af oil - firing power plants operating costs now). The fuel used in nuclear power plants is available and reserves are adequate to cover world's needs well over the year 2000 even with the use of present day technology; the use of fast breeding reactors and reprocessing plants will secure abundant nuclear fuel not for decades, but for centuries.

True, energy conservation represents an important contribution to the energy shortage problems. Still, it can only reduce the growth of the energy demand which would be a nice and valuable achievment; by no means could energy conservation make the building of further power plants unnecessary.

There are some applications mainly in transport and some technologies in various industries where the direct use of electricity is impractical or not possible at all; hydrogen technology is here a most probable answer. Nuclear power could provide sufficient quantity of this new energy medium either by electrolysis or through high temperature reactor technology.

The world energy problem is a complex one. There can scarcely be a simple answer to a complex question. Should an answer be given here, no matter what complexities and possible hazards might be implicated yet, it is simply - nuclear power.

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Table 4 Estimates of total world primary energy consumption in Exajoules [EJ] , world population in millions and energy consumption per capita in Gigajoules [GJ] .

	1978			1985			2000		
	[EJ]	[millions]	[GJ]	[EJ]	[mill.]	[GJ]	[EJ]	[mill.]	[GJ]
Industrialised countries	226.8	1191.9	190	269--315	1268	212--248	375--455	1420	264--320
Developing countries	68.7	2999.6	23	72--89	3617	20--25	145--175	4933	29--35
Ratio of energy consumption in industrial countries energy consumption in developing countries	3.3	-	8	3.7--3.5	-	10.6--9.9	2.6	-	9.1

Table 5 Some of the energy conservation measures [4]

Conservation field		Conservation measure
Road transport	+++	smaller cars, engine improvement*
	++	weight and drag reduction*, micro-processors to improve driving habits*
	+	speed limits, car pooling, mini-buses
	+to0	improved routing, closed town centre, debottlenecking
	++to-	scheduled public mass transit systems
Industry	+++	integrated design and correct choice of new processes*
	++	correct choice of type of energy*, good combustion technology*, waste heat recovery*, insulation, dual purpose plants /heat and power/* heat management and improved maintenance
	+to-	recycling of used materials
Residential buildings	+++	integrated design of new houses*, building regulations
	++	insulation*, draught prooting*, boiler improvement*, improved heating controls*, heat pump*, double glazing*, passive solar heat utilization*
	+	improved efficiency appliances and lighting*, solar hot water*, hot water waste heat recovery*
	+++to0	regulatory limits of indoor and hot water temperatures
	+to0	exhortation/regulation for switching off unused lights and closing curtains
	++to-	district heating*

Note:
- \+ grade of effectiveness
- 0 means "probably not effective"
- \- counter-effective
- * improvement through technological investment /gradings include cost effectiveness/

Table 7 Estimated structure of consumption of fuel and power resources /percent of fuel and power balance/ [5]

Sector of consumption	1970 - 1980		2000			
	Total	Oil and gas contrib.	Total	Oil and gas contrib.	Potential contribut. of nuclear power LWR	HTGR
Generation of electricity	25	13	30-35	10	20-25	25-28
Generation of medium and low grade heat and steam	32	22	25-30	20	8-10	25
Generation of high grade heat	19	14	14-16	10	-	12-14
Mobile and stationary power plants	18	14	16	15	-	-
Raw materials in chemical and petrochemical industries	6	5	10	8	-	-
Total	100	68	100	60		

Table 1 World primary energy consumption 1955 - 1975 in Exajoules /EJ = 10^{18} J/

	1955	1960	1965	1970	1975
Coal	53.33	64.75	65.92	70.91	79.11
Oil	27.83	38.68	57.13	85.26	109.29
Natural Gas	11.72	18.17	27.25	38.09	48.64
Elektrical power from Hydro and Nuclear power plants	1.5	2.64	3.52	4.39	6.74
World total	94.35	124.23	152.95	198.65	243.78
Proportion of resources on total consumption in %					
Coal	56.5	52.1	43.1	35.7	32.5
Oil	29.5	31.2	36.8	42.9	44.8
Natural gas	12.4	14.6	17.8	19.2	20.0
Hydro and nuclear power	1.6	2.1	2.3	2.2	2.7

Table 2 Specific primary energy consumption in 1975 in Gigajoules per capita /1GJ = 10^9J/

Country	
Quatar	770.0
USA	322.4
Czechoslovakia	187.6
Federal Germany	158.3
USSR	149.5
China	14.6
India	5.9
Bangladesh	2.9
Burundi	0.3

Table 3 Number of hypothetical "Energy Slaves" per capita in 1975

Country	
USA	537
Federal Germany	264
China	24
India	10
Bangladesh	5
Burundi	0.5
World average	100.0

Table 6 Primary energy production 1985 - 2020

	1985		2000		2020	
	EJ	%	EJ	%	EJ	%
Coal	115	24	170	25	259	26
Oil	216	44	196	28	106	11
Natural Gas	77	16	143	21	125	12
Nuclear power plants	23	5	88	13	314	31
Hydroelectric power plants	24	6	34	5	56	6
Renewable and unconventional	33	7	60	9	140	14

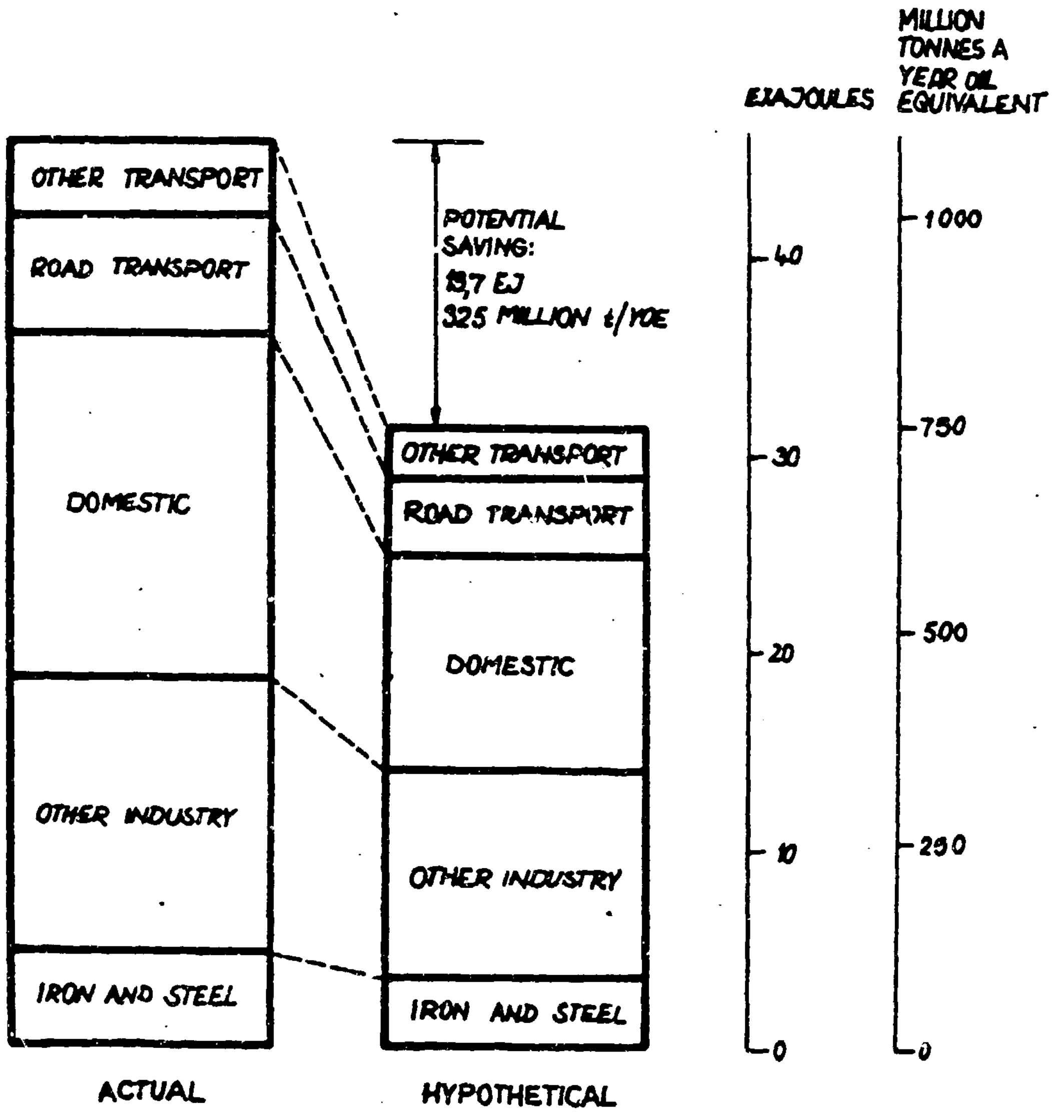

Fig. 1 The potential for improved energy efficiency /W. Europe 1975/ [4]

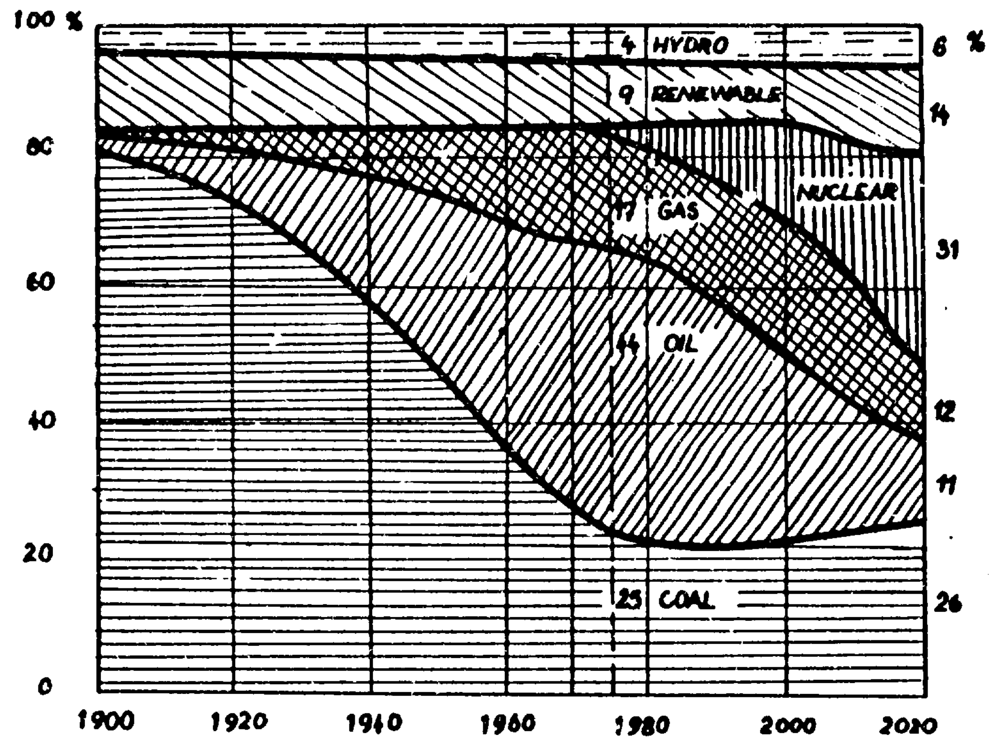

Fig. 2 Proportion of primary energy resources 1900 - 2020