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OPTIMISING THE UTILISATION OF ENERGY IN THE LONG-TERM PLANNING OF ECONOMIC DEVELOPMENT

I. A Brief Analysis-in-Retrospect of World Energy Development

The analysis of the evolution of the world energy situation throws up a number of "energy paradoxes".

The 20th century has been given a number of epithets, each of which, directly or indirectly, refers to the expansion of humankind's technological capabilities. In the last quarter of this century, vistas of the practically unlimited availability of various forms of energy have opened up. Yet it is precisely in this period that the capitalist world is undergoing a destructive energy crisis, which has shaken with the greatest force (as another paradox in itself) those capitalist countries with an elevated scientific-technological potential which have explored the exploitation of geothermal, solar, aeolian and other sources of energy not without success (1).

The scientific-technological revolution has resulted in a grandiose expansion of the energy resources available to humankind. Part II below presents some data on this historical evolution of energy consumption in the world. During the entire history of humankind up to the year 1965, energy consumption added up to 85 billion tons of coal equivalent (tce), 42 billion of which was consumed between 1940 and 1965.

Table 1 presents world demand for the fundamental types of energy in selected years. It emerges that, over the

120 years between 1860 and 1980, the world consumption of these types of energy increased by a factor of 19 overall or by a factor of 6 in per caput terms (4).

Table 1 - Historical figures of world energy consumption

	1860	1900	1920	1940	1950	1960	1965	1970	1975	1980 (forecast)
World primary energy consumption, million tce	552	959	2117	3152	2700	4700	5802	7200	9000	10630
Idem, per caput, tce	0.46	0.59	1.15	1.47	1.16	1.75	1.9	2.0	2.3	2.6

Over the period of time envisaged in Table 1, not only did world demand for the fundamental types of energy increase, but the consumption pattern of fuels also changed substantially. A century ago, 80% of primary energy was used for space heating and other household requirements and only 20% in production and transportation. By today, this relationship has been reversed: household uses account for only a quarter of the world consumption of energy.

Another fact revealing the qualitative change in primary energy use is that, in 1900, less than one per cent of total energy consumption went to generate electricity, whereas the corresponding figure today exceeds 25% (1).

The ceaseless expansion of the world energy complex is revealed by the fact that the world consumed as much energy over the 20 years 1951-1970 as over the entire preceding century, and almost as much energy over the last hundred years as over the entire prior history of humankind (3).

The rates of fuel extraction and of energy consumption have been especially high over the last 15-20 years. Of the cumulative coal extraction of the last 100 years, one-half concentrated in the last quarter of the period. The rates of petroleum extraction were even more forced: one-half of cumulative petroleum extraction over the last hundred years fell into the last ten years.

The vehement growth of the demand for energy has suggested to a number of experts the notion that the resources of primary energy will have been practically exhausted by the end of this century. And if, by the year 2000, nuclear energy will not be available on an industrial scale and in large enough quantities, then a world energy famine may well rear its head.

In our days, concrete dates of the exhaustion of the principal sources of primary energy have been put forward. For example, the renowned Indian physicist Bhabha reckoned that energy reserves will be exhausted in less than 30 years in Asia and the Far East, in less than 40 years in South and Central America and in less than 65 years in the Middle East. Pessimistic forecasters have foretold even briefer spans of time: 13 years for Asia and the Far East, 19 years for South America, 35 years for the Middle East and 48 years for Africa.

A multitude of different factors have contributed to the emergence of and widespread belief in these pessimistic forecasts concerning the non-renewable energy resources. The rapid spreading of the "theory" of imminent exhaustion of petroleum deposits was due above all to the propaganda of the giant petroleum monopolies intent on justifying their aggressive policies in a number of countries and continents, the petroleum resources of which they have expropriated and have been exploiting at extremely fat rates of profit.

A survey of the information currently available on the non-renewable energy resources should not lose from sight the relatively small depth to which our planet has been explored. Taking an orange as an Earth model, the depth which exploration has reached (and even that not over the entire area by far of dry land and of the continental shelves) is comparable not even to the peel of the orange but to the flimsy paper in which it occasionally comes wrapped. Progress in deep drilling will as a matter of course expand significantly the fuel and energy reserves of the world.

Today's rates of industrial growth entail the rapid development of the energy sector in practically every country of the world. The petroleum and natural gas industry is caught up in a process of vertiginous growth. The number of petroleum- and gas-producing countries increases every year, and the extraction of these fuels is growing at substantial rates. In 1947, world gas output was just 73 billion cu.m., but a quarter of a century later (in 1972) it had exceeded 1200 billion cu.m. Petroleum output rose from 320 million tons in 1945 to more than 3 billion tons in 1980. Over the same period, the number of petroleum-producing countries rose from 45 to 65. At present, exploration for petroleum and natural gas is going on in more than 120 countries.

Even these few indicators provide a first idea of the vigorous development, within the world energy industry, of the hydrocarbons sector, decisive for the current energy balance of the world.

It is important to point out that the rising percentage of high-grade fuels in the energy balance has contributed greatly to a rising efficiency of production. For example, the replacement of solid fuels by natural gas permits to save fuel and to raise the output capacity of plant by

10% and 2 to 4% respectively in ferrous metallurgy,
30% and 5 to 10% respectively in aluminium production,
25 to 30% and 10 to 12% respectively in copper production,
6 to 7% and 2 to 4% respectively in electricity generation.

Does all this mean that humankind can, without detriment to the development of its forces of production, avoid future increases in the extraction and consumption of the other primary fuels, e.g. coal, and can concentrate on the more economic types of fuel (petroleum and gas, and, in the future, nuclear energy)? The energy crisis has dispersed this illusion.

Today, the pressing need for a harmonic development of world energy use patterns is emerging with increasing insistence.

II. Specifics of the Future Development of World Energy Development

It is usual in research into the laws governing the development of the world energy complex to distinguish three periods.

The first period (1860 to 1913) was characterised by the uninterrupted, rapid growth of energy consumption.

Owing to a number of economic and political factors, the period between the two world wars was characterised by an unstable growth of energy consumption. Nor did any clear-cut trend of consumption emerge in the years after World War II, when the economies of a number of countries had to be put back on their feet. For all these reasons, the beginning of the second period is placed in the year 1950 (but in 1960 for the US, to exclude the influence of the Korean war and of the Suez crisis), and its end in 1973, the year of the energy crisis.

The third period of evolution of the world energy complex began in 1973 and is still going strong today. During the third period, the development of the world energy complex hit a number of specific problems. On the expeditious solution of these problems depends the future growth not only of the energy complex but also of the world economy as a whole.

1. As regards world energy development in the period before us, an enhanced tendency to save fuels and energy is to be one of the factors likely to cause fundamental changes in the energy economy, including

- the maximum possible reduction of all losses of fuels and energy (during the processes of extraction, transportation, transformation and consumption),
- a more economical use of fuels and energy,
- priority to a lower energy intensity in the design and engineering of machines, mechanisms and technological processes.

Even if, in the earlier periods of development of the world energy complex, the minimisation of energy consumption was not always considered a prime requirement of selection among machines, mechanisms and technological processes, this requirement has become a fundamental one in our days. For example, the automotive industry of the US is faced with the difficult problem that, before the energy crisis, the average American motor car consumed 35% more fuel than the average Japanese or West German car, the reason being that, until fairly recently, the prices of fuel and energy were significantly lower in the US than in the other developed capitalist countries.

The five-year period 1976 to 1980 may be considered as the beginning of a qualitatively new phase in the development of the world energy situation (4).

Table 2 - World energy consumption increment

Five-year period	1961-1965	1966-1970	1971-1975	1976-1980
Increment of the world consumption of energy, tce	1,102	1,398	1,800	1,630

Table 2 presents the five-year increments of world energy consumption over the last 20 years. The increment is seen to have been 1.1 billion tce in 1961-1965, 1.4 billion tce in 1966-1970 (an increase by a factor of almost 1.3), and 1.8 billion tce in 1971-1975 (an increase by the same factor). In 1976-1980, on the other hand, the world consumption increment of all types of energy was only 1.63 billion tce (less than 91% of the increment over the preceding five-year period).

2. The emphasis on energy saving may significantly slow but not stop a rather strong ongoing growth of world energy consumption.

In our times, forecasts on the consumption of all types of energy up to the year 2000 have been coming thick and fast (although, of course, not all of these are equally reliable). The most pessimistic (highest) forecasts, which do not admit the impact of energy-saving efforts on the evolution of the world energy complex, reach the conclusion that, by the year 2000, energy consumption will have attained 70 billion tce, up by a factor of almost ten against 1970.

Some researchers reckon that per caput energy consumption will attain 4.7 tce in the year 2000. By a UN forecast, world population will attain 6.5 billion by 2000. Hence, world energy consumption should surpass 30 billion tce in that year.

It is the lower limit of the forecast, which appears in Table 3 (2), that seems more credible.

Table 3 - Estimated energy demand, all fuels, in the year 2000

Indicators / Country groups	Population, billions	World average, per caput energy consumption, tce	World energy consumption overall, billion tce
Socialist countries	2.0-2.1	6-7	12.0-14.7
Developed capitalist countries	1.0	6-7	6.0-7.0
Developing countries	3.3-3.4	2-2.5	6.6-8.5
Altogether	6.3-6.5	3.9-4.6	24.6-30.2

3. The prices of fuels and energy rose sharply and in jumps during the energy crisis period. They will go on growing in the short term, albeit more slowly and smoothly. This is to be ascribed to the following factors:

- limited cheap petroleum and gas reserves,
- the increased costs of the struggle against the pollution of the environment,
- the intensification of the struggle waged by the developing-country producers of fuel and energy, united in exporters' associations, against the policies of the international monopolies intent on maintaining the dependent positions of the young states in the international market of fuels and energy.

4. There is currently a rather considerable uncertainty as to the techno-economic feasibility of the large-scale utilisation of a variety of new energy-generating processes, which might replace petroleum and natural gas in the ceaselessly expanding world energy budget. The forecasts concerning the dates of entry into large-scale exploitation of the non-traditional types of energy and their impact on the world energy balance also appear rather unreliable.

III. Resource Bases of the Individual Fuel-industry Branches

One of the global problems which precede the optimisation of energy resource use in the long-term planning of economic development is the analysis and forecasting of the fundamental types of fuel and energy reserves.

Let us briefly describe the resource bases of the principal types of fuel, petroleum, gaseous, coal and nuclear.

As regards hydro power resources, let it suffice to point out just that, in the industrially developed countries, the bulk of technically and economically viable hydroelectric sites has already been developed. The remaining hydro power resources of these countries are not being developed, for one or several of the following reasons:

- remoteness from the centres of electricity consumption,
- protection of the environment,
- the excessive costs of development.

Significant undeveloped hydro power resources remain only in certain regions of Asia, Africa and Latin America.

The petroleum industry

In the course of the 20th century, no other energy resource has had an impact comparable with that of petroleum on social and economic development.

Most of the specialists agree today that the depth of the Earth contain about 1,300 billion tons of crude petroleum, of which 840 billion tons (or almost 65%) have not yet been discovered geologically. Assuming that only 30% of the geological reserves is recoverable, the petroleum at the disposal of humankind is 390 billion tons (including 41 billion tons already extracted).

According to other calculations, only 185 to 290 billion tons of petroleum can be extracted. The present proven recoverable world petroleum reserve has been estimated at 91.6 billion tons (5).

Table 4 presents the distribution of the proven petroleum reserves over the various non-socialist regions of the world in the year 1978 and the cumulative output of those in 1971 through 1978.

The gas industry

In comparison with the development of the petroleum industry, that of the gas industry has been held back, despite

Table 4 - Proven reserves and cumulating production of petroleum, billion tons

Region/country	Proven reserves (1978)	Cumulative production, 1971 through 1978
All capitalist and developing countries	74.87	17.33
Middle East	50.78	8.02
Africa	7.71	2.23
North America	6.90	4.20
Central and South America	3.56	1.79
Western Europe	3.24	0.28
South-East Asia, the Far East, Australia and Oceania	2.68	0.81

Table 5 - Proven reserves of natural gas, 1976

Countries and regions	Reserves, trillion m^3	Percentage share of world reserves
USSR	26.0	40
Middle East	14.5	22
North America	8.2	13
Africa	5.9	9
Western Europe	4.0	6
Far East	3.2	5
South America	2.2	3
Chinese PR and the CMEA Six	1.0	2
World	65.0	100

the availability of substantial reserves of natural gas, ei-
ther independently producible or associated with petroleum,
essentially by two factors: (1) the considerable costs of
transportation and (2) the very limited feasibility of storage.
This situation has been changing, however, and natural gas
is becoming the basic fuel in many regions of the world.

Information on natural gas reserves is inadequate for
those countries which have an insufficient domestic demand
or lack the means of transportation for export. Hence, the
approach to the estimation of natural gas reserves has been
different in different regions, and the deviations in the es-

timates do not correspond to real differences in geological potential. Reserves of gas condensate, being linked as they are to the reserves of natural gas, have been established even less accurately.

The proven reserves of natural gas in various countries and regions of the world (4) are shown in Table 5.

The coal industry

The degree of dependence of the world economy on fossil organic fuels is revealed e.g. by the fact that the share of those in the world energy balance is about the same today as it was at the beginning of the century. Yet the share of coal, which at the beginning of the century satisfied 95% of humankind's total energy demand, has declined to about 33%.

Structural change in recent years in the world energy complex, aiming for a return to the less efficient but also less exhaustion-prone fuels, is a difficult process faced with a great deal of inertia. Hence, the longer-term reorientation of the world energy balance from petroleum and natural gas to coal, in the making today, will necessitate a scientific-technological revolution in the extraction, transportation, transformation and utilisation of coal.

A major share of world coal production comes from underground mines, but in a number of countries open-cast coal mining is expanding apace. The principal consumers of coal are today (and will be in the foreseeable future) the thermal power stations and metallurgy. Largely replaced by petroleum and natural gas in the chemical industry, in the transport sector and in space heating, coal is unlikely to regain its lost positions in those spheres.

The bulk of the world solid fuel resource is situated North of 30° N. Lat., largely in four countries: the USSR, the US, China and Canada. Table 6 shows these four countries to possess more than 90% of the world resource (4).

Surveys by various groups of experts have found that only 1,200 billion tons of the world coal resource is in the workable category, and only slightly less than half of this (550 billion tons) is recoverable at the current level of sophistication of the coal industry.

The cumulative quantity of coal extracted from the depths of the Earth so far has been some 130 billion tons,

Table 6 - World fossil fuel resources

Country/region	Total resources, trillion tons	Proven recoverable (workable) reserves, billion tons
USSR	5.71	136
US	2.93	186
Chinese PR	1.01	38
Canada	0.11	6
Europe (without the USSR)	0.61	127
Others	0.39	58
World	10.76	551

or about one-fourth of the workable reserve and about one per cent of the world resource. World-wide, about 3 billion tons of coal are extracted a year, slightly more than half of it in just the four countries mentioned above as possessing 90% of the world resource. Europe without the USSR contributes one-third of world output, although its share of world reserves is only 6%. India, the South African Republic and Australia are also important coal-producing countries. Practically none of the principal coal-producing countries of the world is constrained by a reserve shortage, but in some of them (especially in Europe) the costs of extraction are very high owing to the depth and thinness of the coal seams, and also to the low grade of the coal.

If the available forecasts concerning the introduction of efficient technologies of coal hydrogenation (liquefaction) and gasification do not turn out to be overly optimistic, then coal use may expand again in transportation, space heating etc. In the last five or six years, in the context of the energy crisis and more stringent environmental protection requirements, work on coal gasification and hydrogenation has seen an extraordinary upswing.

Nuclear energy

In recent years, the contribution of nuclear power stations to electric energy production has been on an increase; in several countries, such stations generate today a significant percentage of total electricity. For example, one-sixth of total electricity output is nuclear in Switzerland and almost 10% in the UK. The share of nuclear power in world electricity generation, 3% today, may according to a number of forecasts attain up to 25% by the year 2000.

Over the next few decades or even beyond them, the predominant nuclear fuel will be uranium. By the year 2000, breeder reactors may have spread considerably; these produce another kind of nuclear fuel - plutonium - while using up their original charge of uranium. Moreover, thorium may also find a widespread use in gas-cooled reactors. The demand for uranium in the world energy market will increase (especially until the large-scale introduction of breeder reactors).

Of the known deposits of cheap uranium ore, the biggest ones are in Australia, the US, Niger and the Republic of South Africa. There are uranium deposits also in the socialist countries of Europe and Asia. The world uranium reserve (excluding the socialist countries) is estimated at five million tons of uranium oxide or 4.25 million tons of metallic uranium. About 80% of the economically viable world uranium reserve is located in the US, Canada, the Republic of South Africa and Australia.

The average concentration of thorium in hard rocks is more than four times the average concentration of uranium. The thorium most accessible to industrial use is largely concentrated in the mineral monazite. Large reserves of monazite are known in Europe, in the beach sands of India and Australia and in the US. Since world demand for thorium does not exceed one thousand tons a year, the proven reserves of this nuclear fuel exceed its consumption by an extremely broad margin.

IV. The Optimisation of Energy Use in the Long-term Planning of Economic Development

The economically viable world energy reserves have been estimated at about 4000 billion tce. Accordingly, humankind is provided with traditional energy reserves for the century before us. If coal, petroleum, natural gas, hydro power and nuclear energy are used optimally, and so are the hopeful new energy resources, humankind will have to face no energy famine. The energy resources of our planet are large enough for the deficits of natural raw materials to be overcome in the long run.

Nevertheless, the difficulties facing the development of the world energy complex, in the countries of capitalism above all, are very real and significant ones. They are due first and foremost to the struggle put up by the petroleum monopolies, and also to the difficulties of finding an optimum energy use pattern.

A reduction of the arms race, for which the USSR has been struggling so consequentially, might be the most fortunate means of solving the energy problems of the world. First of all, it would significantly reduce the consumption of the different petroleum refining products. Secondly, some of the finance which is currently being spent on armament could be diverted to more intensive research into and development of new energy resources and also to an expansion and modernisation of geological exploration.

The majority of experts has expressed the conviction that the control of nuclear fusion by the synthesis of deuterium will be achieved in this century yet. The thermonuclear reactor is bound to become the most efficient heat-generating device of the early third millennium: the "burning" of just one atom of deuterium liberates 100,000 kWh of energy. The world oceans contain billions of tons of deuterium; accordingly, humankind is not menaced by an energy famine in the third millennium, either.

The optimisation of energy use in the long-term planning of economic development is a complex problem. Let us point out the following trends of enhancing the efficiency of development of the fuel and energy complex:

- a tendency to intensify fuel and energy savings,
- an acceleration of scientific-technological progress,
- a restructuring of fuel and energy consumption,
- the maximum exploitation of the internal reserves in every branch of the energy complex.

The first two of these should be regarded as exogenous (external to the energy complex proper: they are in fact the principal ties between the systems "energetics" and "economy"), whereas the last two are to be regarded as endogenous (internal to the complex).

1. In the long-term planning of economic development, the forecast growth of energy consumption in each sector must be scrutinised in detail in order to find out what is

more beneficial to the economy: infusions of capital to ensure the adequate growth of fuels extraction and energy generation, or investment into the expansion of energy-saving measures.

For example, several studies have shown that expenditure on improving the thermal isolation of dwelling and working spaces will pay for themselves in two or three years, thanks to the reduced consumption of space-heating fuels. The cost of converting road transport from gasoline to diesel will pay for itself in three or four years, thanks to a substantial reduction in fuel costs and also in the volumes of petroleum production to be planned.

The branchwise analysis of development in the energy complex shows that, in a number of these branches, the efforts at overcoming the inertia of the established trend of development have been insufficient. For example, a confrontation of the short-run changes in the techno-economic indicators of the production and consumption of energy reveals that production expansion can be reduced if part of the investment finance earmarked for it is diverted into energy-saving measures. Such structural changes in the growth of production and consumption of energy and, by the same token, of the national-economy sectors linked with the energy sector permit to achieve significant benefits in the national economy.

The fifteen- to twenty-year forecast of the production of fuels and energy can, as shown by a preliminary analysis, be lowered by 25 to 30% if part of the finance which would have been needed to ensure the forecast expansion is channelled into

- the improved thermal isolation of constructions, especially those coming up in the northern regions,
- a significant boost to the conversion of road transport from gasoline to diesel,
- an intensification of the development and introduction of fuel- and energy-saving processes, machines, mechanisms and so forth.

2. An analysis of development in the branches of the energy complex reveals that the first mineral deposits to be developed are always the economically most viable ones, as regards both their mining-geological features and their distance from the consumers. As a result, a deterioration

over time of the techno-economic indicators of fuel extraction and transportation is an objective reality.

The acceleration and intensification of scientific-technological progress in both the extractive branches of the national economy and in the other branches linked therewith (including geological exploration) is the only factor apt to slow or stop (or in certain cases even to reverse) this adverse influence of reserve depletion on the development of the petroleum, gas and coal industry.

3. One of the fundamental features of the energy complex is its great capital, labour and resource intensity combined with the substantial inertia of its development trends. However, changes in the reserve bases of the different branches of the energy complex and the far from uniform success of science and technology in its different directions of advance may necessitate restructurings of energy use patterns over the period encompassed by planning.

The principal problem of the development of the energy complex is to modify fuel end-use patterns by a branchwise, productwise and technologywise restructuring of production as an indispensable prerequisite to a less material- and labour-intensive trend in economic development. It should be pointed out that the resulting improvement in the qualitative and quantitative indicators of the energy endowment of work is to permit not only to raise labour productivity and the efficiency of the economy overall, but also to solve a number of important social problems. On the other hand, the transformation of the technological structure of production must reckon with the necessity of reducing the use of the capital- and labour-intensive types of fuel and energy.

For an example of the significant returns to be achieved by a restructuring of the energy balance, let us cite the results of some multivariant calculations on the replacement of petroleum by natural gas. The energy complex of the USSR may perform such a techno-economic manoeuvre of development if

- the process of replacing petroleum products by natural gas as boiler and furnace fuel is intensified (especially in the power stations, including those currently in operation, where dual firing is provided for, and also in those where a full conversion to natural gas is feasible),
- the exports of petroleum are reduced and offset a by corresponding expansion in natural gas exports.

Such a structural transformation of the energy balance may bring the Soviet economy by reducing the expenditure to be earmarked for the development of the energy complex (by 4.8 to 6.0 billion rubles over the 12th Five-year Plan, 1986 to 1990).

The efficiency of development of the energy complex as a whole may be increased significantly by exploiting the efficiency reserves of the sector and of each of its branches. In the long-term planning of economic development, a special importance is to be attributed to the complex of measures concerning the ways and means, the deadlines and effects of exploiting the said reserves (including the accelerated attainment of projected productivity at the newly constructed and reconstructed facilities, higher ratios of conversion of prospecting boreholes into producing ones, the modernisation of the economic mechanism in such a way as to ensure the productivity of the facilities brought onstream at a level not below that warranted by the mining-geological features of the deposits, and so forth).

Even reckoning in the long-term planning of economic development with just the four above-mentioned means of raising the efficiency of development in the energy sector should bring a substantial economic benefit.

NOTES

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