METHODS USED FOR ESTIMATING THE ENERGY REQUIREMENTS OF THE FUTURE AND THE REASONABLE DEVELOPMENT OF POWER SUPPLY

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The reasonable approach to the technical development of power economy is governed, in the first place, by *the energy requirements of the future. Long-term energy balances* are being prepared all over the world to determine the needs of energy in the future and attempts are made to develop more and more accurate methods to increase the reliability of these balances.

These trends have a special importance in countries poor in energy. The discovery of nuclear energy has raised quite a number of questions in connection with the energy supply of the future as, for instance, finding solutions best suited to local conditions, in order to achieve a reasonable development of long-term power supply.

Though a long-term estimate of the future needs of energy involves difficulties whose solution requires far-reaching theoretical and practical considerations, and though the reliability of any estimate decreases with the remoteness of the term, the United Nations Organisation has extended the investigation of power demands as far as the 2000th year.[1]

One of the gravest *difficulties* is the correct assessment of *economic problems* and their effects. This is why in documents of this kind such problems are not dealt with in detail but are just touched upon. Problems of economic character, though difficult to evaluate, do exist and exert their influence, consequently, to study their importance is an imperative task.

A long-term forecast of the power supply in the future requires, first of all, the determination of the *quantity and quality of the needs that are likely to arise*, as well as the *quantity and quality of sources* that are now at our disposal and that can be expected to be available in the future ; hence one of the *first* tasks is to prepare a long-term *balance of* the quantity and quality of *energy* to be needed.[2]

[1] United Nations, *World Energy Requirements in 1975 and 2000.* Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Vol. I, p/902, New York 1956.

[2] Rational methods for drafting long-term energy balances have been discussed lately András Lévai, professor at the Technical University, Budapest in his *A magenergiahasznosítás várható szerepe Magyarország távlati energiamérlegében* (The Possible Influence of the Utilization of Nuclear Energy on the Long-term Energy Balance of Hungary), published for official information. I shall discuss the drafting of long-term energy balances after prof. Lévai.

Different methods are used for drafting energy balances.

According to *one* of these methods, the following factors are to be taken into account : *the consumption statistics* of the last known year (with due regard to consumption data over a longer period determined in the past), *the available sources of energy, the analysis of the increase of consumption* (including the investigation of the so-called exhaust velocity of the sources), and the consumption to be expected in the future.[3] These data constitute the elements of the balance.

In the foreign literature some authors follow an *optimistic* method, some follow a *pessimistic* method of forecasting.

The *pessimistic method of estimating* the energy potentials reckons with a substantial increase of production, an industrial, economic, etc. *boom*, on the one hand, and departs from *smaller values* in assessing the resources, on the other.

The *optimistic method of estimating* the energy potentials assumes a relatively *modest* development of the *consumption demands*, on the one hand, and departs from *more favourable*, higher values for the resources, on the other.

Unless some apparent reasons prevent us from following it, the middle course between the two methods seems to be expedient.

When drafting energy balances it is usually assumed that the unit cost of energy consumption remains *essentially* unchanged during the period covered by the estimate. This fact considerably decreases the trustworthiness of the energy balances and thereby the authenticity of the estimates of future energy requirements. Especially in Hungary, where the production cost of coal is relatively high, a substantial decrease in the cost of energy and the *increase of specific energy consumption* can be achieved by the installation of atomic power stations only.

The energy balances distinguish between energy sources "*introduced*" to the consumer and the types of energy "*utilized*" by the consumer on the spot. (The types of energy introduced are either primary, i. e. basic sources, like coal, crude oil, natural gas, water power, or secondary sources, like electricity, household gas, coke, etc.) This distinction allows of establishing the ratio of energy actually "utilized" by the consumers and of the amount "introduced", i. e. the "*consumption efficiency*", the ratio of secondary and primary energy utilized, i. e. the "*efficiency of energy conversion*", as well as the product of these two efficiencies, i. e. the "*total energy efficiency*".

[3] Another method expounded in an OECC report (The Organisation for European Economic Co-operation, *Europe's Growing Needs of Energy*, Paris 1956) suggests the estimate to be based on the following data : the *gross national income* and the *energy consumption to be expected*, making a preliminary estimate of them for the whole area of the OECC Member countries on the basis of the present rate of employment, taking into account the growth of the population, the number of working hours and the changes occurring in productivity. A further step is to estimate the increase of energy demands to be expected for industrial and household consumption. The last step is to sum up the estimates concerning the different countries.

The energy balances generally take into account *every type of energy*, and are not limited to any one of them (as, for instance, electric energy) because the different types of energy utilized are often interchangeable.

Later we shall come back to the economic significance of the interchangeableness of the types of energy.

The targets set for long-term energy balances are usually approached *from different angles with different methods*, and the results thus obtained are collated and the final decisions taken.

The commonest methods are the following :

a) The so-called *aggregate method* takes into account *vast consumption areas* (e. g., parts of a country, continents, the whole world) and relying upon the *statistical data of the past* endeavours to deduce certain regularities from the production values of power sources, i. e., from the mean values of energy consumption.

Its *advantage* consists in quickly yielding *approximately reliable data* and in showing the summarized result of the influences exerted by the most different *effects* which *compensate each other* fairly *well* over the vast consumption area investigated. The smaller the economic unit investigated with this method, the smaller is the probability of compensation.

Its *drawback* consists in the fact that it is often rather difficult or sometimes even impossible to deduce the reasons of certain important changes from statistical data referring to vast areas.[4]

Different methods can be used for deducting from the data of the past the annual percentage of the increase, for instance, in the production of the

[4] Relying upon statistics reaching back into the remote past, the aggregate method may yield an interesting set of data concerning the *degree of utilization of the aggregate basic sources of* (industrial) *energy of the world and its energy consumption* (coal, liquid fuel, natural gas, water power). See United Nations, *World Energy Requirements in 1975 and 2000*, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy.

On examining the data for the period between 1863 and 1953, it becomes obvious that wars, economic crises and the years of prosperity involve booms and slumps in the development. Within the above-mentioned period, in the years of economic prosperity the annual increase of the total energy production was 4,5, i. e. 5,5 per cent, while including the years of regression the average increase of the production of industrial energy sources, uniformly calculated, was not higher than 3,25 per cent. For the same ninety-year period, in the *United States*, the production of industrial energy sources show an average increase of 4,7 per cent per annum, whereas the production of all energy sources during the same period increased by no more than 2,5 per cent.

In the OECC countries the annual increase of energy consumption was 4,8 per cent after 1945 which, of course, includes post-war restoration. See The Organisation of European Economic Co-operation, *Europe's Growing Needs of Energy*, Paris 1956.

The average increase in the *production of all energy sources in Great Britain*, taking into account the domestic consumption, was 1,85 per cent between 1850 and 1950. See G. H. Daniel, *The Energy Requirements of the United Kingdom*, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Vol. 1, P/388, New York 1956. The annual increase of the aggregate energy consumption in *Europe* (without the USSR) was 1,6 per cent for the period of 1925—1953. See *The Electric Power Situation in Europe in 1955*, Economic Commission for Europe, Committee on Electric Power. EP Working Paper No. 61. 4 Oct. 1956.

above-mentioned industrial basic energy sources or in general in the energy requirement of industrial production or of the different branches.[5]

b) Another method of forecasting departs from *assessing the energy consumption of the most important sectors in the national economy* (industry, transport, agriculture, household, etc.) and, relying on these data, tries to make a reasonable estimate of these same energy requirements for the future.

c) With a view to increasing the reliability of the estimated data, *the study of the consumption over areas that can be regarded as energetically homogeneous*, as, for instance, the *industry of electric machinery*, gas production, *steel metallurgy*, etc. might be expedient. Inferences concerning the development of similar power demands in the future can be made from the energy consumption of such areas. *The latter two methods can be called synthetic* because the forecasts rely upon the values obtained from the different branches of industry, i. e., from their areas that can be regarded as energetically homogeneous.

In calculating average values certain *single factors* must not be lost sight of, like the installation of certain energy-absorbing industries (light-metal industry, chemical industry), lasting depression, or a sudden boom following the making up for lags caused by possible war-time devastations.[6]

Having now analysed the methods of forecasting we may enquire into the reason *why the economic problems are usually neglected in preparing long-term energy balances.*

This may be traced back to several reasons, as for instance, to the partial absence, in the first place, of *reliable unit-price and investment statistics*, and of exact *files on the interchange of the sources of energy as a function of their prices*, etc. In addition to this, even *an approximate accuracy is hardly attainable* in assessing the future effects of quite a number of economic factors which, then, are simply disregarded in order to decrease the vagueness of the estimates.

On the other hand, such an approach to the problem is contradictory because if economic aspects are neglected, the accuracy of the balance and

[5] P. Ailleret, *Estimates of Energy Requirements*, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Vol. 1, P/326, New York 1956.

[6] The report of the Economic Commission for Europe, for instance, divides the aggregate consumption into *industrial, transport, household* sectors and *losses (La Situation de l'énergie électrique en Europe en 1953/54*, Commission économique pour l'Europe, Comité de l'énergie électrique, EP/82, 28 janvier 1955) and analyses the increase of consumption for the years 1928 to 1953. Accordingly, the total increase of electric energy consumption during these years was 5,5 per cent/annum, that of the industrial consumption 5 per cent/annum, of transport 1,7 per cent/annum, the losses amounted to 5,6 per cent/annum, and the figure for household consumption was 7,5 per cent/annum. This conspicuous development can be accounted for by the inclusion of new household consumers, on the one hand, and by the new demands of the earlier consumers.

the trustworthiness of the forecast are bound to be impaired. If, for instance, in countries producing today electrical energy from coal at a relatively high price the thermo-power plants will be substituted by atomic power stations yielding considerably cheaper energy, then the cheaper production cost of the source of energy and the concomitant decrease in unit cost of electric energy will allow an unforeseeable *increase in the per capita specific consumption of electric energy*. And the past decades testify to the fact that the *utilization of the basic sources of energy is subject to a constant transposition*. The expensive sources of energy (as, e. g. coal) are replaced by less expensive ones (as, e. g. mineral oil or water power) and the consumption conditions are subject to parallel changes following the changes in the production costs of energy.

Important economic interrelations of varying extent at different places and at different times, but not to be neglected in preparing energy balances, appear between the *transposition*, interchange *of the basic sources of energy* and the substitution of expensive ones by cheaper ones, on the one hand, and the *quantity* and *quality of consumption*, on the other.

The next step is to enquire into the *economic significance of the decrease in the unit cost to be expected in the future.*

An American author, P. Sporn[7] states that the *unit cost of electric energy* — in most industries — *is not decisive for the development of the branches* of industry. More important factors are in this respect the *consumption requirements*, the *manpower demands*, the *prices of raw materials*, the *transport costs*, etc., excepting, naturally, the energy-absorbing industries like the electro-metallurgy of steel, aluminium metallurgy, etc.

The *increase of energy consumption* is, in his opinion, more the function of the *capital supply* necessary *for new consumer installations.*

Irrespective whether or not this statement holds good for capitalist relations of production, the issue merits as well to be seriously studied and considered.

Sporn's compatriot K. M. Mayer[8] studies *the effect of the decrease in the unit cost of energy in connection with the interchange of power sources.* The power plants having the highest *economic potential* are the most promising for the future. He means the source of energy, by the use of which *the unit cost of the energy* produced in a given power plant is lower than the unit cost of the energy that can be produced in other power plants by utilizing other sources of energy.

The economic assessment of such problems on a world scale is rendered even more difficult by the fact that the *unit cost of energy*, the *amount of*

[7] P. Sporn, *The Role of Energy and Nuclear Energy in the United States*, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Vol. 1, P/468, New York 1956.

[8] K. M. Mayer, *The Economic Potential of Nuclear Energy*, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Vol. 1, P/475, New York 1956.

power that can be generated and, therefore, within the whole national economy, its *significance for the country is extremely variable* (and depends, for instance, on the development of the economic life and on the power reserves of the different countries).

At any rate it would be highly welcome if the organs compiling statistics on power economy (such as the UNO, the OECC, etc.), beside developing more uniform principles for consumption statistics, were to bestow more care on *compiling statistical data suitable for assessing economic problems, on unifying them and, at the same time, on facilitating international collations*, and to include into the work now done mainly by engineers, such specialists as are well trained in political economics and statistics.

Summing up what has been said above, the *investigation of* the following more important *economic aspects seems to be indicated :*

a) The *effects* of the possible *interchange of the basic sources of energy*, due, in the first place to the changes in their production costs.

b) As to the secondary sources of energy, *the effects of the future interrelation of the main economic indexes of electrical energy production* as the ratio of *constant* and *variable* costs (e. g., as a result of automatization, the creation of large power plants or large factory units). It remains to see *what part will be played by the cost of fuel* and other expenditures, mainly *costs of investment, in the future development of the unit cost of energy.*

When investigating the cost of *items coming under the heading of investments*, it seems to be expedient to make a thorough study not only of the decrease in the costs to be expected in consequence of the presumable *improvement of efficiency*, but also of the consequences of the decrease in the expenses of *raw metarials* (except fuel) *necessary* for power generation, to be expected in the future (e. g., the replacement of metals by synthetic materials).

c) The presumable *effect of the changes in unit cost* of electric energy upon the *requirements of consumption*, upon the development of major industries, including the *energy-absorbing* ones and their influence.

d) Finally, the *effects* of growing power generation on the increase of the *country's* industrial potential, on *new export possibilities and upon similar but remote economic interconnections.*

If the constant production costs are going to become the decisive factor in the future, the unit cost forecast for electric energy will depend, *in the first place, on further technical development* (the rise of the technical standard) and, to a certain degree, also on the *changes* that are likely to occur *in the prices of* the non-fuel type *raw materials* necessary for power stations.

The *rate of future technical development* and its economic significance — being factors partly depending on discoveries — are *difficult to assess.*

The prices of *raw materials* are likely to change under the decisive influence of the prices of the products manufactured in the synthetic industries now developing with rapid strides and gaining ground all over the world.

A somewhat more reasonable possibility seems to present itself for analysing the *effect of the future decrease in unit costs upon* the development of the consumption within *certain groups of consumers.*

The further development of economic investigations, finally, requires the *establishment of a uniform method for examining the economic efficiency of major investments* (mines, power stations, etc.) *in the energy economy.*

In socialist economy the *economic efficiency* of major investments (such as, e. g. the establishment of power plants) are usually examined from three different angles.

The first angle is *national economy* as a whole, the second is the relevant *industry* and *enterprise* and, finally, the factors enhancing or reducing the efficiency of investments are taken into consideration during *execution* (realization).

The first question to be answered from the angle of national economy is *whether the investment is necessary* and *to what extent* it serves proportional (well-balanced) development of the countries' economic life. Hence the *full social efficiency* of building power plants can only be determined by making allowance for and by estimating every favourable (active) and unfavourable (passive) effect it may have upon satisfying in the long run all necessary social requirements.

When complying, to a certain extent, with certain investment requirements in energy economy (active effect), it should be realized what other important branches of the national economy may fall short of certain investments (passive effect).

Hence, the first thing to be settled is the *order of importance* of the investment requirements to be met and then the order of magnitude of the investments to be remarked for the different branches.

The decision concerning the branch of industry or, even more so, enterprise, will be taken according to the *most expedient form* (for instance, thermo-or hydro-power plant) the investment found necessary can assume. In this respect we suggest the use of Prof. Strumilin's method for determining the coefficient (δ) of the relative efficiency which examines the *ratio of operation thrifts* of collated schemes and of the *surplus investments* rendering them possible.

The *inverse value* of Strumilin's coefficient of the relative efficiency yields the so-called *time of recovery*, i. e. the term within which the surplus investment is recovered as a result of the reduction of production costs.

According to this method the decisive index of economicalness is the annual reduction of production costs calculated for one currency unit. Hence

$$\delta = \frac{C_1 - C_2}{I_2 - I_1}$$

where C_1 and I_1 are the investment costs and the production costs, respectively, of the minimum version of the plan, and C_2 and I_2 are the investment costs and production costs, respectively, ensuring higher technical standard (consequently, reduced production costs).

The inverse form of the equation

$$\frac{I_2 - I_1}{C_1 - C_2} = \frac{1}{\delta}$$

expresses *in years* the time within which the investments are recovered.

It is obvious that when investigating economicalness, *factors and relations other than this index should also be assessed correspondingly.*

Only by considering all relevant factors can be obtained a clear picture and a solution most favourable for the national economy.

Then we proceed to investigate the factors that might increase the *costs of realizing the scheme* found most suitable and to consider the outcome of these investigations. (Such as the possible term of realization connected with the consequences of the natural conditions, the most suitable way of meeting power requirements, control of *safety in planning.)*

Hence *the meticulous disclosure of economic relations* and their correct assessment *in preparing long-term energy balances,* — even if their evaluation is an intricate and difficult task full of contradictions, — *can by no means be neglected, though it must be admitted that owing to their uncertainty sometimes they are much less suitable to be expressed in figures than the deductions that can be made from the data of past consumption, from the estimate of energy sources or from the rate of exhaustion.*

When preparing long-term energy balances it must, however, be kept in mind that forecasts — even if yielding indispensable information for the planned development of the energy economy, — are by nature of but a *vaguely informative character,* and the data obtained thereby, being variable in time, require a manysided evaluation and careful circumspection.

Since, in spite of their deficiencies, they are for the time being indispensable in planning, constant attempts should be made to improve the investigation methods and the collecting of data. Finally, beside the more or less measurable economic aspects, planning must also rely on the effects of development that cannot be expressed in figures but to a certain extent can be deduced from experimental facts.

Summary

The paper deals with the metods used for preparing long-term energy balances and concludes to the fact that, in spite of their vaguely informative character, they yield indispensable information for the planned development of the energy economy.

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