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11 December 1979

East Europe Report

ECONOMIC AND INDUSTRIAL AFFAIRS

(FOUO 14/79)

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EAST EUROPE REPORT

ECONOMIC AND INDUSTRIAL AFFAIRS

(FOUO 14/79)

CONTENTS PAGE

CZECHOSLOVAKIA

ENERGY FLOW AND ECONOMIC GROWTH ANALYZED

Prague POLITICKA EKONOMIE in Czech No 8, 1979 pp 801-817

[Article by Jan Klacek and Miroslav Stainer: "Required Energy Flow and Economic Growth (A Macroeconomic Analysis and Projection)"]

[Text] From the standpoint of economic theory, the analysis of the role of energy in the reproduction process represents an unusually complex and until recently a somewhat overlooked problem. In contrast to this, it is possible to see how the practical questions of energy policy have assumed a downright strategic importance for most countries. Insuring a continuous energy flow to the reproduction process of a developed economy, together with the population trend and corresponding food production, is regarded as the essential condition for long-term development on a worldwide scale.

As to energy, principal attention is focused on energy resources, their dynamic development, structure, the development of their costs and prices. Together with this research, an increasing number of studies deal with the analysis of energy needs, their determinants, or potential savings and conditions which would facilitate savings. In this context, the present article deals with one specific though obviously important topic.

We are trying to examine the possibility of modeling the required flow of energy to the reproduction process under conditions of the Czechoslovak economy. The article consists of three parts. In the first part, we state the theoretical premises for examining the role of energy in the reproduction process. In the second part, we analyze the interrelationship between energy consumption and product output over time by comparing their dynamics on the basis of statistical data of a macroeconomic character. On the basis of this analysis and initial theoretical considerations, a model of the required energy flow is designed and its empirical estimate accomplished. It is applied to energy consumption in the production sphere of the CSSR as a whole and in industry in particular. The concluding part contains conditional projections for a medium long-range period into the future.

1. Theoretical Premises

As indicated by Karl Marx and confirmed by economic developments in developed industrial countries, the growth of productive forces is closely linked to far-reaching changes in the position of man in the production process. In the process of the industrial revolution, man gradually frees himself from physical (mechanical) labor in the production process. The transition to activities involving "facilitating regulating and controlling the material reactions between self and Nature"[1] is, among other things, made possible by the conscious utilization of knowledge relating to energy conversions, their regulation and systematic control.

In this context K. Marx also introduces the term auxiliary materials[2] in the production process on which the required form of energy depends. For the user the energy carrier constitutes a specific raw material which gradually replaces directly expended human labor and, together with other production factors, participates in the production process as the motive power of large-scale manufacture.

"...The machine, which is the starting point of the industrial revolution, replaces the worker, who handles a single tool, with a mechanism which operates a number of identical or similar tools, and is driven by a single motive force whatever the form of that force may be...[3]

The role of energy, obtained from inanimate nature, in the reproduction process is not, of course, exhausted by the replacement of physical human labor in operating the means of production. The exploitation of this energy creates the working and general living conditions for man's participation in the reproduction process of the contemporary economy.

As will be seen below, changes in the dynamics of energy use depend also on the implementation of scientific-technical progress and on structural changes, both in the production factors and the product.

On a lower level of abstraction, although still on a highly aggregated level, we can illustrate the processes of drawing energy in the reproduction process of a planned economy in a diagram--see Schematic No. 1.

In the first place, there is the relationship between the necessary quantity of energy--both as a total as well as structure by carriers and types of energy--and the planned economic development of individual national economic users of energy.

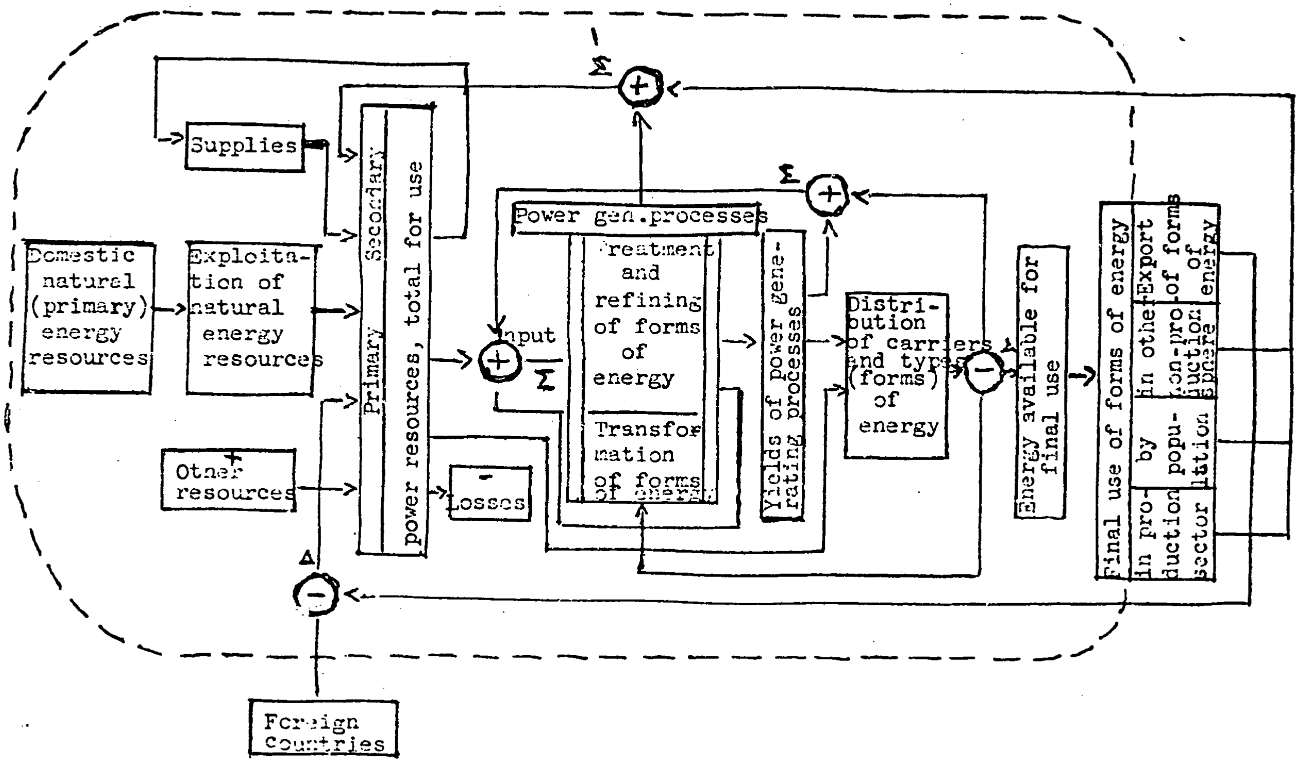
From the schematic, it is clear that the necessary quantity of energy and its forms appear on two albeit interdependent levels, namely:

1. As the need for primary energy resources, by volume, and

2. As energy needed for final use, by volume.

Schematic No. 1

Basic Phases of Energy Flow



The difference between these two levels corresponds to the sum of energy losses and operating needs for energy in individual power generating processes, that is in the process of treatment, transformation, transportation and transmission of power resources and forms of energy. This difference represents so-called consumption by the energy complex itself which is part of consumption for production and whose scope is determined by technical and economic factors. The minimizing of energy losses and operating needs in the power generating processes to a technically and economically justifiable level is one of the sources for increasing the final use of energy at the given consumption rate of primary energy resources.

Energy requirements for final use in the national economy depend upon different factors in the production sphere and in the nonproductive sphere, respectively. In the production sphere, the use of energy is an indispensable condition for carrying out individual technological processes and is, therefore, linked to the creation of the total product or net product with close ties to the inputs of other production factors. The magnitude of this requirement is determined by:

a. The scope and structure of social production;

b. The machine-man ratio in individual technological processes;

c. The level of management, organization, etc. of such processes and the resulting degree of energy utilization.

In the nonproductive sphere, the final use of energy appears in processes connected with the reproduction of labor power (heating, operation of household appliances and so on), and is therefore the factor which directly affects the standard of living. From the standpoint of creation and distribution of net product, this use of energy is affected by the magnitude of social and individual consumption. Its development usually depends on the general trend in the living standard--the volume of individual incomes and expenditures, the available quantity of consumer goods (particularly the so-called durables), changes in the lifestyle, etc.

In contrast to the final use of energy, its need on the level of primary energy resources is determined by the requirement to secure the operation and development of the energy complex. Most of the primary energy resources are derived from the exploitation of domestic sources. The other, minor part of primary energy resources is acquired through imports; it is thus linked to the foreign trade balance and to the expenditure of foreign exchange.

A similar situation exists in the subsequent phases of the technological process of the energy complex. Virtually all primary energy undergoes the processes of treatment and energy transformation. From this, one can draw the simple conclusion that, under the given technical conditions of their acquisition and treatment, the need for primary energy resources predetermines, at the same time, the amount of those funds from the total social product (or national income) which must be earmarked for the operation and necessary development of the energy complex.

The taking into account of the objective existence of the different nature in the relationship between the two above-mentioned levels of need and the utilization of energy with respect to the remaining area of the national economy is of practical significance in the analysis of the development of the energy complex. It is so precisely because this different nature determines the basis for specifying the substantive contents of this analysis.

2. Relationship Between Energy Consumption and Production Volume--A Retrospective Analysis

For purposes of a restrospective analysis and even more so for future projections on a national economic level, it is necessary to formulate certain working hypotheses on the functional (or casual) interdependences between the energy flow and macroeconomic variables. These hypotheses, enabling verification by means of empirical data, bring a certain order to the relationships under analysis.

Most analytically-oriented studies of power engineering link the energy flow in the national economy more or less closely to the production volume during an appropriate time span.

It is therefore not surprising, if for the CSSR, we find a relatively close interdependence between the volume of the total social product (Q) or national income (Y) on the one hand and the total flow of utilized energy (E) in the production sphere on the other (see Diagrams No 1 and No 2).[4] As the diagrams indicate, the long-term consumption of the total energy flow increases less than proportionately in relation to the production increase which implies the declining energy consumption of Czechoslovak economic growth.

Furthermore, we shall examine the dependence of electric power consumption on the production volume. Electric power is the principal energy output at the end of the process which starts with the mining of coal. This dependence is much closer than is the case with total energy (see Diagrams No 3 and No 4). In contrast to the dependence of total energy consumption on the production volume, the relationship between electric power consumption and production differs in one respect. As is evident from the diagrams, individual observations reveal a steeper interdependence than in the previous case. With the increase in production volume, there is only a very slight decline in electric power consumption both in the production sphere as a whole and in industry.

In view of the fact that the observed interdependences appear to be close--both on the basis of empirical data over a long period and in various disaggregations by sectors[5]--one can presume that the hypothesis of the dependence of energy consumption and particularly electric power on the product output volume is consistent with the actual observations.

Diagram No 1

Dotted diagram showing the dependence of final use of energy in the production sphere on the total social product

1965 = 100

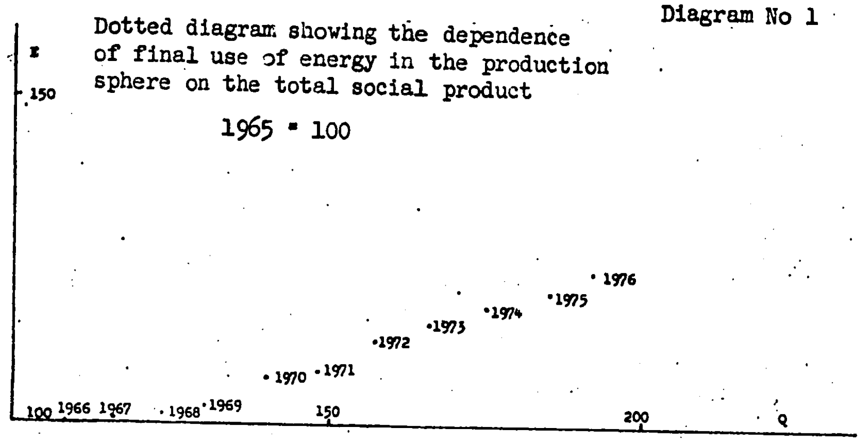


Diagram No 2

Dotted diagram showing the dependence of final use of energy in the production sphere on the total national income

1965 = 100

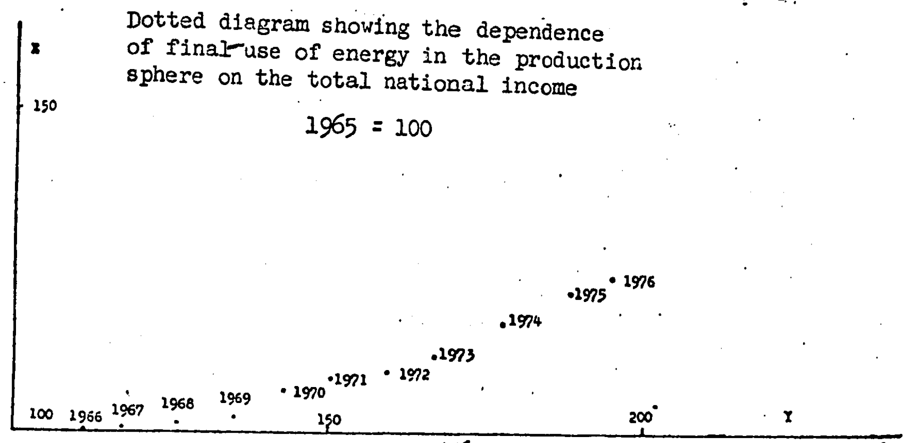


Diagram No 3

Dotted diagram showing the dependence of electric power used in industry on the total social product in industry

1965 = 100

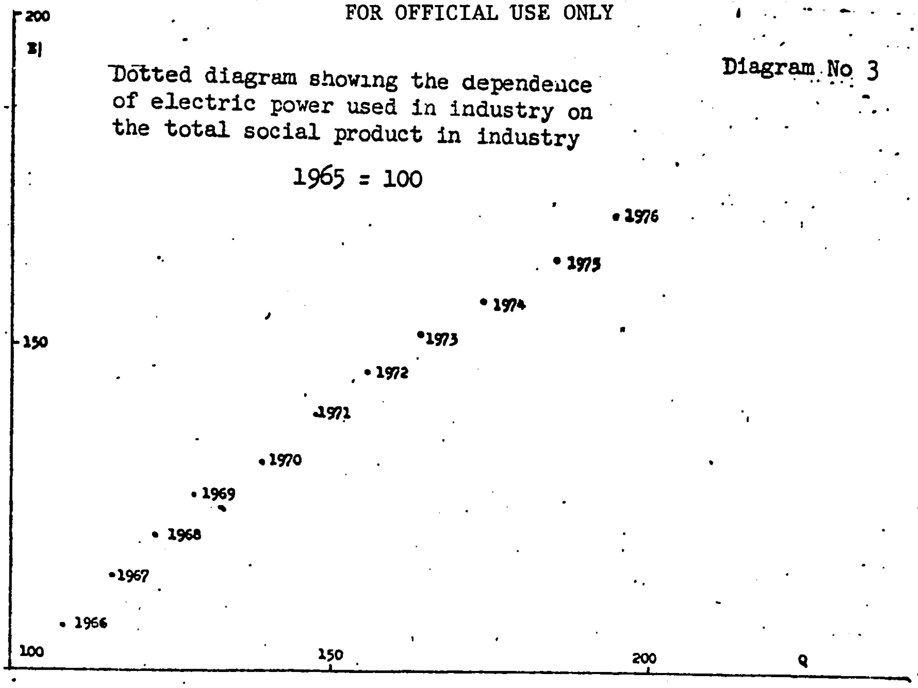
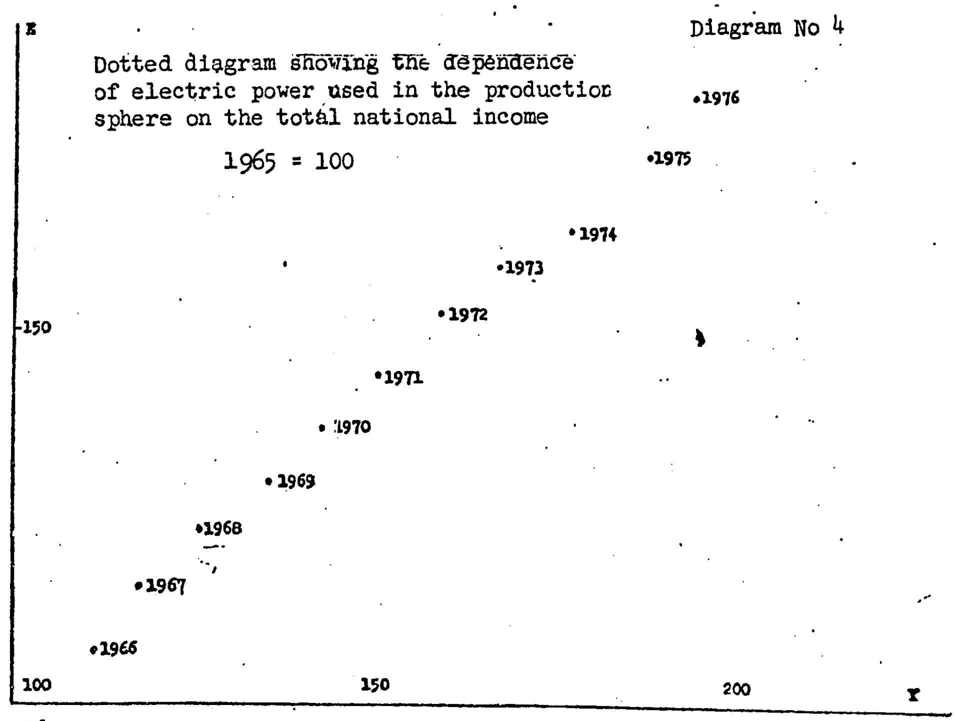


Diagram No 4

Dotted diagram showing the dependence of electric power used in the production sphere on the total national income

1965 = 100



At the same time one can conclude that the form of dependence examined indicates a decline in energy consumption with product increases, that is to say, in this case also in terms of time. The decline in energy consumption is obviously brought about both by the structural changes and implementation of energy-saving scientific-technical progress, including the introduction of new energy-saving technologies which results in the decline of specific energy consumption.

In aluminum production, for example, which requires a large amount of electric power, the consumption declined by approximately 15 percent in 1976 in comparison with 1972. Furthermore, consumption of electric power per ton of rolled material declined by 4 percent during the 1969-1976 period.[6)]

In addition, the very shift in the material structure of final energy consumption from coal to refined types of fuels and primarily to electric power makes it possible to reduce losses in the conversion of energy, and thus favorably affects energy requirements of the national economy.[7)]

As to the effect of structural changes, however, development has by no means been straight. The development of branches and entire sectors resulted in increased energy requirements in some instances (electric steel, agriculture, etc.).

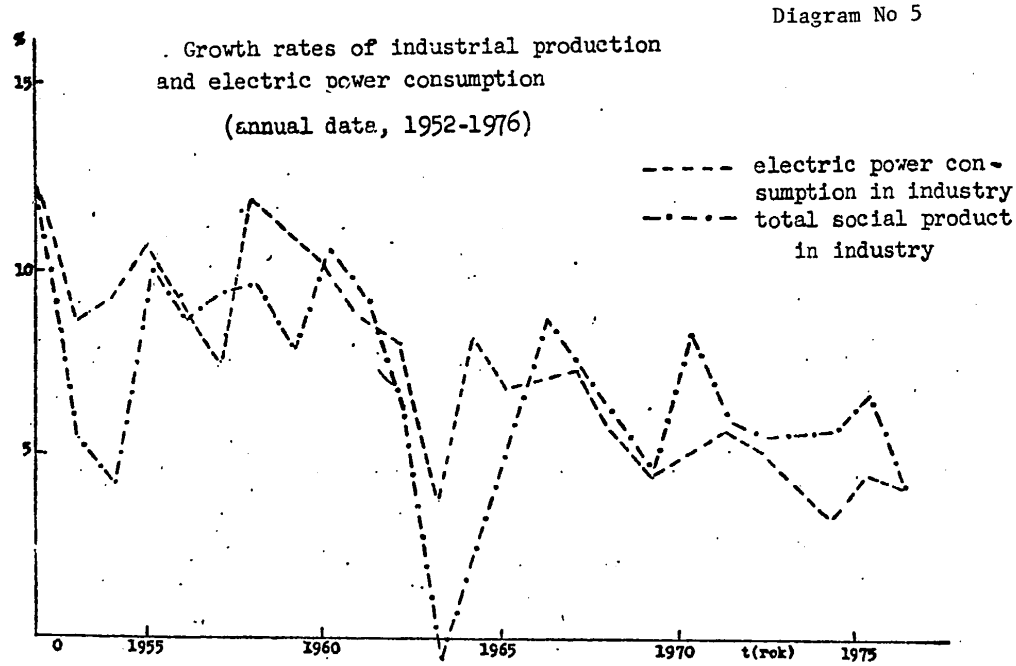
The observed decline in overall energy requirements was, thus, achieved by structural changes--some of them reducing and others increasing energy consumption--which, combined with the effects of scientific-technical progress, do not always necessarily lead to the decrease of energy requirements.

The dependence of energy consumption on production volume, on the structure of the economy and on the implementation of scientific-technical progress is part of the technical balance relationships in the reproduction process. In addition, one can observe additional interdependences which are not related to the technical balance.

The effect of factors falling in this latter category can be followed in a more detailed study of the dynamics of electric power consumption and production (see Diagram No 5). The diagram makes it clear, for example, that in periods of high growth rates of industrial production (1950, 1960, 1966, 1970) the growth rates of electric power consumption are relatively low in comparison with the rates of production increase. On the other hand, when the dynamics of production declines (1953, 1963, 1971/1972), the dynamics of electric power consumption usually decrease, but substantially less than the dynamics of production. The result of observed dynamic changes are short-term fluctuations in the elasticity of production in relation to energy consumed.

A similar movement was analyzed in regard to the dynamics of production and employment.[8)] In the case of electric power, this apparently implies the declining rate of its use and the changing degree of supply limitation, which could help explain the dynamic changes observed. The situation is also affected by weather conditions and other accidental influences.[9)]

Diagram No 5



3. Model of Required Energy Flow

As the short-term influences obviously divert and remove, in both directions, the examined dependences from the technical balance relations, we first formulate a theoretical model for a long period, when it is justified to disregard the short-term influences. In its first variant, the theoretical model should therefore reflect exclusively the technical balance relations or, to put it differently, the trend dependences in the reproduction process. The factors in the short-term changes will be, in the examined relation, taken into account, when the model is specified in details.

Let us take as the point of departure the production function for the potential product "Q^x" which is the function of labor input "L", basic assets input "K," energy (and/or materials) input "E" and influences of scientific-technical progress "R."

$$Q^x = f\,(L,K,E,R) \qquad (1)$$

The potential product is defined as the maximum product attainable with available resources or--which is equivalent--the product volume manufactured with the full and stable utilization of resources over a long period of time.

The production function (1) appeared in literature until recently only exceptionally in the sense that it also included the energy flow as one of the inputs.

Since the production function, as originally developed, was intended to clarify the determinants of added value)of net production), the energy input or more generally the input of raw materials, industrial materials, semi-finished products--in other words, the overall intermediate product--was not regarded as the input explaining the level of the maximum product. It was argued that the components of the intermediate product constituted an output of the production process in its initial phases and that this output was in turn affected by "traditional" factors--input of labor and basic assets, and the effects of scientific-technical progress. In other words, K, L and R on the aggregate level conclusively determine not only Q^x, but also energy flow E.

Recently, however, many authors[10)] no longer accept this seemingly convincing argumentation. There are several reasons for that. In the first place, the above mentioned argument only applies to the input of energy and, more generally, to the input of the intermediate product of domestic origin. This argument fails, however, in the case of smaller economically developed countries which import a substantial part of their energy or energy resources. In an open economy, it is, therefore, justified to regard imported energy and energy resources as a separate input into the production process.

This view is undoubtedly encouraged also by the increasing scarcity of classical energy resources which causes, though exceptionally as of now, the energy flow to become the limiting factor in the growth of the product or, to restate it in different words, that other sources of growth cannot be fully utilized until the necessary energy flow is assured.[11)]

Finally, energy and the intermediate product used are not simply consumed in the production process, but affect the characteristics and quality of the product in a varying degree depending upon the resources used. From this standpoint, the quantity of national income even depends upon the intermediate product used.

The production function in the formula (1) for the level of the potential product describes the supply aspect of the economy. From our standpoint, it is expedient to deduce a relationship which would determine the quantity of the required energy flow. We obtain it by solving formula (1) for the variable E.

$$E = f^1 (Q^x, L,K,R) \qquad (2)$$

This equation can be called the function for the required energy flow which is indispensable for achieving the level of the potential product. From the econometric standpoint, equation (2) is based on the assumption that the variables on the right side of the equation are given or determined in some other way. In other words, the energy flow is not regarded as the limiting factor, but is, on the other hand, endogenously determined by the other macroeconomic quantities.

The conception of the energy flow as a limiting factor in the growth of the product would tend to bring us back to equation (1) with the following modification:

$$Q^x = \min f\,(L, K, E, K) \qquad (3)$$

In case of an acute energy shortage, given limited possibilities of substitution between E on the one hand and L, K on the other, function (3) could be specified as

$$Q^x = f\,(E, R_E) \qquad (4)$$

in which R_E represents the effects of energy-saving scientific-technical progress.

The interdependences (1) and (2) or (3) and (4) can be called the laws of technical balance. They assert themselves over a long period of time because they depend also on the long-term growth of productive forces.

A More Detailed Specification of the Model

The long-term growth of productive forces or the laws of technical balance naturally do not exhaust all factors determining the required energy flow in the reproduction process. This is clear already from equation (2) in which the potential product "Q^x" is among the determinants of the required energy flow. The actually achieved level of product "Q" usually differs from this potential level during the short-term and medium-term period.[12) The causes of this difference simultaneously affect the actual energy flow in the reproduction process. In the objective reality of the short-term, the actual energy flow is, thus, determined not by the potential level of the product, but by the level actually achieved. The determinants of the currently achieved level of production and, thus, also of the required energy flow, are more complex in character than mere technical balance factors. Accordingly, we could distinguish between the technologically-required energy flow and the actually-required energy flow.

Short-term or medium-term determinants which work together with the already mentioned laws of technical balance can be divided into two basic groups.[13) The first group contains accidental influences. Accidental influences include changes in the weather, trends in losses in the national economy, sudden and unforeseeable changes in foreign trade conditions and other factors which are exogenous in character.

The second group represents factors which are gnoseological in character, linked to the already achieved level of central planning and management of the reproduction process, to the choice and implementation of economic policy. This group also includes the system of management and planning for the national economy, although this system is rather long-term in nature.

From the second group of factors it is necessary to mention changes in the use of the national income. These short-term and sometimes rather pronounced changes can result in fluctuations in the dynamics of investment, inventories, individual consumption and deposits on savings accounts.[14] In the case of the CSSR economy, the dynamics of the foreign trade balance in particular has a specifid role.

Short-term changes in these valves create complex, dynamic, adjusting processes in the economy and may, in turn also cause short-term changes and fluctuations in the dynamics of the creation of national income. Independent of these changes in the structure and dynamics in the use of the national income, which usually arise as early as when annual national economic plans are put together, pressures may also be exerted by changes in the dynamics and structure of consumer demand (and savings deposits) originating in the decision-making processes of the consumer. These changes by themselves may produce short-term movements in the national income, although their scope will usually be narrower than in the previous case.

Apart from these effects, secondary inter-sector chain reactions are produced on the aggregate level which cause fluctuations in the use of capacities in individual sectors and branches of the national economy.[15]

The advantage of a centrally planned economy is the objective possibility of reducing, as the fact-finding process improves, the magnitude of the deviations between achieved national income and potential product. The fundamental prerequisites thus exist for significantly reducing the difference between actual economic development and the dynamically balanced trajectory. Between the prerequisites for a substantial reduction of these disproportions and the practical implementation of these prerequisites, there may be a considerable difference caused by objective and subjective reasons. Analysis of economic development in the CSSR and in other socialist countries confirm this conclusion.[16]

For these reasons, the first, as well as the second, group of factors must be taken into account in a more detailed specification of the model. From the first group, that is from among accidental influences, it is in first place the effect of the weather which, as empirical analysis has demonstrated, is of great importance with respect to the quantity of the required energy flow. This part of the required energy flow does not represent a direct input into the production process, but creates general conditions for the actual production process (heating, lighting, ventilation, etc.).

From the second group, we attempt to model the factors in the short-term movement of the national income by means of delays spread over a period of time. Futhermore, the existing system of management and planning forms the institutional framework within which the enterprise sphere participates in the drafting and implementation of the national economic plan. Besides other factors and to the extent to which it provides the various economic entities with a motivational structure for the stimulation of more economical use of resources, the system of management and planning in a way also affects the quantity of the required energy flow and the resulting energy requirements of economic development of the CSSR.

An imbalance between the energy sources and needs, particularly with regard to electric power, arose in the second half of the 1960's and has been recurring ever since. Such a situation, if it is of a long-term nature, logically leads to the design of a model in the form of the production function within the energy complex rather than to a model of the required energy flow for the national economy. An estimate of the equation depicted as relation (4) was, therefore carried out experimentally. An artificial variable representing supply limitation was introduced into the type (2) equation.

A specific question is the effect of the level and structure of energy prices on the quantity of the required energy flow. In the first place, we have in mind the potential effect of price changes on the economical use of energy, where considerable reserves undoubtedly exist. In the second place, we must consider potential structural changes brought about by the rational replacement of one form of energy with another, cheaper form.

To put it differently, we are considering both changes in the general price level and the differentiation of relative energy prices. On the theoretical level, this is an analogy of price elasticity of demand or cross price elasticity. There are reasons for incorporating the presumption of nonzero price elasticity in the theoretical model. This presumption is closely related to the target function of the enterprise, to the system of retirement benefits' and wage regulation on the part of the enterprise sphere, as well as to the rational behavior of the consumer. From the long-term standpoint, it would then be necessary to examine the nature of the price system in relation to production costs.

All of these important questions must, of course, be judged against the background of the finding that changes in the price level of energy and in the structure of energy prices were only sporadic and rare in the period of postwar economic development and particularly in the period for which statistical data are available.

Model for an Empirical Estimate

The design of the model for an empirical estimate is based on equation (2) which we expand to include the effect of the variables mentioned earlier. It includes, primarily, the short-term change in the current production level as compared with the potential level which is modelled by the delays spread over a certain period. Simple models of these delays use a delayed value of variable E_{t-1}. We replace potential product Q^x directly with current level Q. Furthermore, we consider the effect of weather changes T and the variable of the supply limitation of the energy flow--artificial variable D (0,1). Accidental variable "u" should reflect other accidental influences. The price level of energy is designated as p_E.

It is necessary to specify the technology of the production process in equation (2). We will presume that basic assets once installed will be operated by a definite, unchanged number of workers during their entire service life--that is that no new fixed assets will be retroactively added to replace human labor. Mutual substitution among these two factors exists only in regard to the future, when new additional fixed assets are being selected. The presumption of ex post facto fixed proportions allows us to simplify equation (2) by omitting variable K. The basic assets thus represent a relatively nonessential factor, while human labor represents the "bottleheck" of the reproduction process--a limiting factor of growth.

The magnitude of labor input L thus determines the degree of utilization of the basic asset supply and, thus, also maximum product Q^x. Labor input will also indirectly determine the quantity of the required energy flow which is necessary for the operation of machines.[17] This casuality, of course, applies to stationary conditions--that is provided that the level of knowledge and its utilization remain unchanged. Under dynamic conditions, of course, energy-saving, neutral or more energy-costing scientific-technical progress may assert itself which will change these relationships. For simplicity's sake, we shall confine ourselves to the instance of exogenous scientific-technical progress which has not yet materialized but about which we assume that it is energy-saving and which we shall approximate by applying time trend "t".

We then obtain the following function:

$$E_t = f\,(Q_t,\ E_{t-1},\ L_t,\ T_t,\ D_t,\ pE_t;\ u_t) \qquad (5)$$

Equation (5) contains all fundamental determinants of the required energy flow on the aggregate level. Their structure is now substantially more comprehensive than in the form of equation (2).

In the first approximation, function (5) can be specified in logarithmic-linear form. The logarithmic-linear form of function (5) enables us to use regressive analysis to estimate the parameters and this form is in agreement with the results of the empirical analysis of time series for Czechoslovakia and with some international comparisons.

An Empirical Estimate of the Model

The theoretical model was estimated in a large number of variants, analysis and description of which would be very long.[18] First, attempts were made to isolate the effect of individual variables on the explained variable E and then more comprehensive designs of the model were estimated.

Below are the estimated equations for the production sphere and industry of Czechoslovakia. As the basis, the annual time series for the 1960-1976 and 1962-1976 periods were used. The energy flow was approximated by use (consumption) of electric power El, measured in units TF, the product by the total social product or gross production in constant prices.[19]

Estimates of equations pertaining to the required electric power flow in the CSSR production sphere (based on the 1960-1976 annual time series)

$$\ln El_t = 1{,}1558 + \underset{(0{,}1970)}{1{,}6216} \ln Q_t - \underset{(0{,}00058)}{0{,}00165}\, t^2 \qquad (6)$$

$$R^2 = 0{,}98 \qquad F = 406 \qquad D.-W. = 0{,}48$$

$$\ln El_t = 3{,}2505 + \underset{(0{,}1558)}{1{,}3241} \ln Q_t - \underset{(0{,}00047)}{0{,}00095}\, t^2 - \underset{(0{,}0273)}{0{,}1091}\, D \qquad (7)$$

$$R^2 = 0{,}99 \qquad F = 567 \qquad D.-W. = 1{,}19$$

An estimate of the production function with the electric power flow as explaining the variable in CSSR industry (based on the 1962-1976 annual time series)

$$\ln Q_t = 4{,}1529 + \underset{(0{,}0546)}{0{,}7409} \ln El_t + \underset{(0{,}00017)}{0{,}00149}\, t^2 \qquad (8)$$

$$R^2 = 0{,}99 \qquad F = 2163 \qquad D.-W. = 1{,}14$$

Significance of symbols:
- El -- consumption (use) of electric power
- Q -- total social product (gross industrial production
- D -- artificial variable (0,1)
- t -- time trend
- ln -- natural lagarithm

These regressive equations represent relatively "successful" estimates in the first phase of research. They were selected according to two criteria. In the first place, the condition was the statistical significance of regressive coefficients, and in the second place their theoretically acceptable sign and numerical value.

The equations remain are confined to the fundamental technically-balanced design of the model [20] [regressive equations (6) and (8) possibly to the formula extended to include the supply limitation--equation (7)].

Generally speaking, the results achieved can be regarded as the first experimental estimate of a model of functional relationships between the required energy flow and some macroeconomic variables in the CSSR. [21)]

According to these empirical estimates, it is possible to judge to what extent the premises adopted in the design of the model on the basis of the statistical data's analysis coincide with reality or to what extent they simplify the observed reality. It follows from the nature of the model that these dependences are likely to be similar.

In the first place, one can conclude from the results that the modelled dependence of the electric power flow in industry and primarily in the production sphere as a whole on the dynamics of production offers estimates of respective elasticities at values significantly higher than one. Furthermore, the estimates of model parameters indicate the scope of energy-saving scientific-technical progress in the past. All instances involve approximation by means of the quadratic time trend whose parameters turn out to be statistically very significant. According to this hypothesis, the effects of energy-saving scientific-technical progress accelerate in time so that they are relatively maximized in the last years of the time series. The growth rate of electric power savings due to these effects accelerates by 0.2-0.3 points annually.

The estimates of parameters of energy-saving scientific-technical progress, however, require an explanation. Relative energy savings can actually be achieved also by the changes in the sector, branch and product structure, including the structure of primary energy resources. The aggregate model cannot cover these changes. One can, however, presume that the parameter in the variable of time trend covers, in addition to the effects of scientific-technical progress, also this type of relative energy savings. It is, therefore, more appropriate to interpret this parameter in a broader sense in line with the significance described above.

Finally, equation (7) has provided a statistically significant estimate of the parameter of supply limitation of electric power with the expected sign. All three equations, however, show low values for the D-W test so that we cannot reject a hypotheses about the presence of residual autocorrelation.

The equations are restricted to the basic technically-balanced design of the model or to the form extended to include the supply limitation. In the course of experimental verification of the model, attempts were made to model and empirically estimate the parameters of all variables listed in function (5). The estimates of individual parameters were more or less successful. The same, however, cannot be said of the estimate of a more comprehensive model as a whole. Here, for the most part, acceptable values of parameters of variables which enlarge the narrow technically balanced scope of the model only by making the original parameters statistically insignificant, were obtained. In some instances, the estimates of a more comprehensive model were statistically insignificant as a whole. As to the individual variables, it has still not been possible to successfully reflect the important influence of weather changes. For this reason, the summary of results is limited to the equations corresponding to the basic form of the model.

From this, one cannot, of course, deduce that the arguments in favor of a more comprehensive model of the required energy flow are no longer valid. We can infer in this respect only, that the selected specifications of the model and their estimates of parameters of additional variables did not produce acceptable regressive equations. Their adequate reflection in the model for an empirical estimate, thus, remain open for future research.

Any subsequent projections of the required electric power flow must also be approached in this sense.

Everything that has been said so far makes clear the hypothetical and experimental nature of analogous projections on an aggregate level. It is only strengthened by the factors of dynamic nature. The projections described below can, therefore, be regarded as only tentative in significance.

Medium-Term Projection of Required Electric Power Flow

Projections or forecasts of this type can be approached in two different ways. The first approach is based on expert judgments, the second on the application of a specific model. For the model approach, we use the regressive equation estimates for purposes of projection. Specifically, we will use equation (7) for the production sphere. The application of this equation for purposes of projection permits two different procedures in regard to energy-saving scientific-technical progress.

The first variant is based on the same premise as the retrospective model which means that energy-saving scientific-technical progress over a period of time and its effects can be approximated by the quadratic time trend even into the future. This approach is, among other things, also supported by the results of the analysis of losses in the production, transmission and use of electric power and by the international comparison of electric power consumption in the CSSR. 22)

The reserves in the form of high specific (per unit) consumption of electric power, as well as in excessive energy requirements of the economic structure offer a certain justification indicating that these savings could, under certain conditions, further accelerate over time. It is, of course, difficult to determine the point at which the possibilities of the most obvious and the most easily attainable energy-saving changes will be exhausted. There is no doubt, however, that the Czechoslovak economy will approach this point for objective reasons in the 1980's.

The continuation of accelerating energy-saving scientific-technical progress can, then, encounter a number of obstacles and will be both technically and economically less easy, anyway. At the least, this would require sizeable investments in research and development, and a consistent application of the results in practice in the form of broadly conceived rationalization programs in energy consumption. This, in turn, would call for a reappraisal of investment activity which, instead of building new production capacities with high energy requirements, should be purposefully oriented toward the rationalization of energy consumption. Even though the first approach in a sense extrapolates the pace of scientific-technical progress--on the basis of the development of industry in the past--also into the medium-term time horizon of the future, it is an obviously optimistic presumption in this case. The problems which we encounter here can be formulated more generally as the conflict between the past and the future or between a relatively successful retrospective model and its always only limited applicability to the future.

Equation (7), after an adjustment for growth rates, has the following form in this instance:

$$\frac{\Delta El}{El} = 1{,}3241\,\frac{\Delta Q}{Q} - 0{,}0019\,t \qquad (9)$$

The growth rate of the required energy flow depends upon the selected growth rate for production and on the accelerating pace of the energy-saving scientific-technical progress (as anticipated).

Table 1 shows the dependence of $\Delta El/El$ on the selected $\Delta Q/Q$ and on the time trend which approximates the effects of scientific-technical progress.

Table 1 Interdependence between $\Delta El/El$, $\Delta Q/Q$ and t (according to equation (9))

$\frac{\Delta Q}{Q}$ \ t	1	4	7
0,05	0,064	0,059	0,053
0,045	0,058	0,052	0,046
0,04	0,051	0,045	0,039
0,035	0,044	0.039	0,033
0,03	0,038	0,032	0,026

If, for example, we project a 4 percent rate of product growth, then the growth rate of the required energy flow will be approximately 5 percent in the first year of the projection, but only 3.9 percent toward the end of the period projected. As to the isolated dependence of $\Delta El/El$ on $\Delta Q/Q$, equation (9) says that a lone percent increase in $\Delta Q/Q$ increases $\Delta El/El$ by 1.3 percentage points[23], other things being equal. Deceleration of production has a quantitatively equal effect in the opposite direction. In other words, the very selection of the product growth rate affects the growth rate of $\Delta El/El$ more than proportionally.

The projection points to a decrease in the rate of $\Delta El/El$ in time and, in the last mentioned variant, $\Delta El/El$ decreases below the $\Delta Q/Q$ level by the end of the period. It is impossible to assert that these developmental trends would be without parallel in the past. At any rate, however, both long-term development in the CSSR and international comparisons shows that the consumption of electric power increeases ahead of product increase.[24] These data show the substantial influence of the acceleration of scientific-technical progress considered in the model and in this sense the projection can be regarded as "optimistic".

Furthermore, it is necessary to point out that our projection is based on the extrapolation of past trends in the production sphere only. We have already mentioned the role of scientific-technical progress. These simplifying assumptions, however, could in a given instance lead to the underestimation of the dynamics of the required electric power flow, rather than vice versa.

According to expert estimates, a number of intended structural changes in the 1980's will obviously result in the increase in the standard consumption of electric power. In the first place, production of electric steels, ferroalloys, thin and medium sheets will be substantially increased.[25] A further increase in standard consumption can be anticipated in connection with the priority development of the chemical industry and of the entire nonproductive sphere. Furthermore, it is likely that the limited supply of liquid fuels and of labor will necessitate technological changes which will result in their replacement by electric power.[26] Although other structural changes will undoubtedly result in relative energy savings, the summary effect, as it seems, will be a noticeable slowdown in the decline of energy requirements, as to electric power, in comparison with trends in the past.

For these reasons, we also carried out a projection for the variant of economic development in which energy savings do not accelerate in time. The second approach to the estimate of the trend in energy savings is, therefore, based on the assumption of a constant, rather than an accelerating, effect of scientific-technical progress (in a broad definition). The quantification is based on equation (9) which is, of course, modified for the constant effect of scientific-technical progress upon the growth rate of the required energy flow.

We chose two modifications. The first (A) anticipates the average rate of energy savings due to scientific-technical progress, structural changes, etc., as it materialized according to equation (9) during the entire 1960-1976 period. According to variant "A," the rate of energy savings amounts to 1.7 percent annually. Variant "B" is based on the recent 1970-1976 period only and energy savings amount to 2.7 percent annually. (In this case, it is, of course, necessary to take into account the unusually favorable course of winter temperatures during the entire period after 1969). We again obtain a dependence between the aggregate increase in the product and the increase in the required electric power flow.

Table 2 Interdependence between $\Delta El/El$ and $\Delta Q/Q$ (log--linear trend in energy savings) -- average annual growth rates

$\Delta Q/Q$		0,05	0,045	0,04	0,035	0,03
$\Delta El/El$	A.	0,049	0,043	0,036	0,029	0,023
$\Delta El/El$	B.	0,039	0,033	0,026	0,019	0,013

Variants A and B furnish average values for $\Delta El/El$, all of which are lower (in the given interval of values $\Delta Q/Q$) than the average quantities of $\Delta Q/Q$ (see Table 1). A critical value is the 5.5 percent growth rate of the product. At values which are higher than this limit, $\Delta El/El$ already is higher than $\Delta Q/Q$.[27)]

Experience with both approaches to the projection of the required energy flow shows that any projection critically depends on the following factors, which are technically balancing in character:

a. the choice of the aggregate product growth rate;

b. the implementation of energy-saving, neutral or energy, costly scientific-technical progress, including all factors which determine it;

c. the development of the structural profile of the economy with reference to energy requirements.

Since this projection is of probable nature, all values for the energy flow in the interval of reliability and only are the decisive quantities not only individual values. Specific, empirically observed values are, of course, burdened also by other factors than those of technical balance. These factors of short-term change create complex adjusting processes without whose identification it is very difficult to discover the laws of technical balance. This study does not exhaust the analysis of these influences and it should be used as a point of departure for future research.

FOOTNOTES

1. See Karl Marx "Capital", Vol 1, Prague, State Publishing House for Political Literature, 1954, p 196, American edition p 197.

2. Ibid. Czech edition p 201, American edition p 202.

3. Ibid, Czech edition p 401-402, American edition p 410. In another passage it is stated: "...a rebirth of artisan production on the basis of machines is but a transition to the factory system, which,

as a rule, also makes its appearance so soon as human muscle is replaced, for the purpose of driving the machines, by mechanical motive power, such as steam or water" - Czech edition p 489, American edition p 503.

4. Dot diagrams are taken over from the work of M. Stainer (1978).

5. In the disaggregation by sectors of the national economy which were also examined, the noted dependence exists in all sectors except transportation. Transportation is the only sector in which energy consumption permanently and absolutely declined despite a production increase. See M. Stainer (1978).

6. See "The CSSR Statistical Yearbook".

7. See M. Cibula (1979).

8. See J. Klacek - M. Toms (1976).

9. The Research Institute for the Economics of Fuel and Power in Prague dealt with the estimate of the effect of excessively high temperature during the 1973-1974 winter period on fuels and energy consumption. The average temperature during the heating season was 4.04 degrees Celsius, while the long-term average was 2.3 degrees Celsius. The authors arrived at an estimated savings at 2-3 million tmp [tons of standard fuel] which amounts to approximately 2-3 percent of the annual consumption of primary energy resources. See A. Suk and associates (1977).

10. See for example E. Domar (1961), B. N. Michalevskyi-J.P. Solovyev (1966), M. Toms (1969), L.R. Klein (1977).

11. In the same way, certain other raw materials could be regarded as factors limiting growth.

12. See for example B.N. Michalevskyi (1972), A.I. Antchishkin (1973), J. Klacek-M.Toms (1976).

13. A similar breakdown was used by N.F. Shatilov (1974).

14. See J. Goldmann and associates (1978), K. Rozsypal (1968), J. Reznicek and associates (1974).

15. See N.F. Shatilov (1974).

16. See for example J. Reznicek and associates (1974), V. Welfe (1974).

17. Approximately 80 percent of energy consumed in the production sphere of Czechoslovakia are used to drive machinery and equipment.

18. See M. Stainer's dissertation for the degree of Candidate of Sciences (1978).

19. Data in parentheses below the regressive coefficients are their standard errors.

20. Includes current production level and actual electric power flow.

21. So far as we know, the previous attempts at modeling and empirically verifying the models in this area were confined to models in which the energy flow is the exclusive function of the time trend transformed in one way or another.

22. For a more detailed comparison, see A. Cervenkova, H. Waisova (1975), M. Cibula (1979).

23. The numerically close values for long-term elasticity of energy in relation to production were obtained also in the modelling of short-term movements of the product by means of delays spread over a certain period. See M. Stainer (1978).

24. See A. Cervenkova-H. Waisova (1975). The consumption of electric power in the nonproductive sphere, which our projection does not cover, may be a correcting factor.

25. See A. Suk and associates (1977), K. Houdek and associates (1978).

26. See K. Houdek and associates (1978).

27. The value of 3.9 percent for $\Delta El/El$ at $\Delta Q/Q = 0.05$ -- variant A -- corresponds to the forecast rate for $\Delta El/El$ which was arrived at though with a different procedure also by the workers at the Institute for Research of Economics of Fuels and Power Engineering in Prague. See A. Suk and associates (1977).

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