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CZECHOSLOVAKIA'S APPROACH TO SECURING ITS PROSPECTIVE FUEL AND ENERGY SUPPLY

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PREFACE

On the occasion of the "IIASA Day" on 4 March 1981 at Prague, C.S.S.R., a workshop was held with the participation of representatives from the Czechoslovak Government, the Czechoslovak Committee for IIASA, and a delegation from IIASA. This seminar focused on "Perspectives of Development of Fuel-Energy Complexes until the Year 2030" from the global as well as national viewpoints.

The present paper highlights the introductory address to the workshop given by Ing. Vlastimil Ehrenberger, CSc., Minister of Fuel and Power. It has been taken up in IIASA's Collaborative Paper Series for several reasons. For one thing, it aptly illustrates the highly interactive nature of communications IIASA aspires to with its National Member Organizations. For another thing, it patently shows how the way of thinking developed in IIASA's Energy Systems Program can benefit the planning of the national energy sector. It is believed that such feedback from the decision-making community should in turn provide a valuable input to IIASA's applied research.

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CZECHOSLOVAKIA'S APPROACH TO SECURING ITS PROSPECTIVE FUEL AND ENERGY SUPPLY*

Vlastimil Ehrenberger

INTRODUCTION

Development of the highly complex and intertwined national energy system is a fundamental requisite for all countries seeking to advance their national economies. For decisions currently taken and investment projects now completed will have their impacts upon the fuel and energy basis still in the first third of the next century.

This fact has been aptly and comprehensively documented for the world by an expert team of the International Institute for Applied Systems Analysis at Laxenburg, Austria. Their analyses have resulted in a remarkable publication on "Energy in a Finite World" (IIASA's Energy Systems Program Group, W. Häfele, Program Leader, 1981). This study does not only render a clear overall picture of the problems underlying the development of national energy systems but also provides interesting stimuli in the field of systems analysis and related modeling approaches. Before this background, Czechoslovakia's energy system (also referred to as FEC, fuels and energy complex) is described in the following in terms of its historical and current development and in an international context. The paper reflects on how some of the stimuli provided by the global study may contribute to the planning and management of national FEC development.

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*Adapted from the address given at the workshop on "Perspectives of Development of Fuel Energy Complexes until the Year 2030", 4 March 1981, Prague, C.S.S.R.

CZECHOSLOVAKIA'S ENERGY SITUATION

Throughout the establishment of the Czechoslovak Socialist Republic heed and high priority have been given to the development of the country's fuel and energy system.

As a result, the total use of primary energy, for example, has increased over the past 25 years, from 42 mtce in 1955 to 105.1 mtce in 1980, while the annual electricity consumption has risen from 15 TWh to 74.5 TWh (Table 1).

Table 1. Development of primary energy consumption in Czechoslovakia, 1955-1980.

Year	Total Consumption Primary energy (mtce)	Electricity (TWh)
1955	42	15
1980	105.1	74.5
1980 index (1955=100)	250	497

But conditions for Czechoslovakia, as for any other industrialized country, in providing fuels and energy as well as other raw or secondary materials have radically and fundamentally changed since the mid-seventies. As a consequence, development of the FEC system will require much more attention from all echelons of management. The country's social and economic development in the eighties and thereafter will largely depend on how efficiently fuels and energy can be used. This fact is at the heart of the country's strategic planning for a higher effectivity of the entire national economy.

From an economic point of view, Czechoslovakia's raw material base, including the national energy sector, appears to be limited and incomplete. The rapid expansion in industry, agriculture, and transport and the advancement in people's standard of living imply that large amounts of primary energy are consumed. This is manifested, among others, by the rising oil and gas imports, which will continue to grow in the foreseeable future. Table 2 gives the historical and projected primary imports in percent of yearly energy consumption, 1960-2000.

Table 2. Shares of imports in primary energy consumption, historical and projected.

Year	1960	1965	1970	1980	1985	1990	2000
%	10.9	18.5	34.2	38.3	38.5-38.7	38.6	36.8-37.3

More specifically, consider the energy situation in recent years. In 1979, out of a total primary energy consumption of 101.3 mtce, 42.5 mtce were covered by imports, 37.9 mtce of which came from the Soviet Union. Crude oil consumption of 18.9 mtce was almost completely (18.8 mtce) imported, mostly (18.3 mtce) from the USSR. 1979 imports of natural gas, on the other hand, were 6.77 Gm^3, out of a total consumption of 7.6 Gm^3. The 1980 natural gas imports of 7.7 Gm^3 were fully provided by the Soviet Union.

This trend toward an ever greater share of imported high-grade fuels in the nation's fuel supply clearly cannot continue, owing to the prevailing global energy predicament. This has been duly recognized and this is why the country's primary energy consumption policy was fundamentally changed already in the period of the Sixth Five-Year Plan (1976-1980). The new policy is to expand coal exploitation for the generation of power and heat and to speed up the implementation of nuclear power projects.

INTERNATIONAL ENERGY COOPERATION

Czechoslovakia has been playing an active role in all kinds of related international projects. This cooperation will be deepened and expanded in particular by tying up additional electric power capacities and by constructing thousands of kilometers of interconnected networks. These plans involve the national systems within CMEA as well as others, wherever possible.

Another high-priority area of this line of coperation between CMEA countries is resource development in terms of new energy sources and raw materials. This effort, which is linked to the program of economic integration of the member countries, is the first among the long-term, target-oriented CMEA cooperation programs in preparation. (More on the target programs, their purpose, and setup will be said at the end of this paper.) As regards the development of the FEC, the following major directions have been set forth:

- Each member country will strive to optimally develop its own primary energy resources;
- Oil and gas pipelines to be constructed jointly will serve to deliver oil and natural gas from the Soviet Union to other CMEA members;
- The CMEA countries will set up a unified electric power system that is to be backed up by large power centers, which in turn will be connected by very high voltage grids;
- According to a joint program extending to 1990, nuclear power stations will be built in these countries; construction of the plants and production of related equipment will be covered by special contracts of cooperation;
- Major scientific and technological efforts will be made focusing on the provision of new energy sources and on the reduction of energy requirements in all sectors of the national economy;

- Major energy-intensive production capacities will be constructed jointly, with due consideration of optimum plant size and proximity to large energy sources.

The energy issue is gaining increasing importance in the global context and for the future of all mankind; it is certainly advisable therefore to prepare for the long-term solutions of related problems in the framework of international cooperation, such as, for example, along the lines of the United Nations and regional organizations.

THE FUELS AND ENERGY POLICY

The main objectives of our fuels and energy policy are incorporated in the various projects that are part of the State target programs on the fuels and energy economy. These projects fall into 3 main categories:

(a) One set of projects relates to brown and hard coal mining. Throughout the eighties, brown coal will remain the foremost fuel base for power and heat generation and the heating of dwellings. Hard coal will continue to provide the raw material base for coking; **it will help expand cooperation with CMEA countries** and serve as a significant source of hard currency.

(b) Another group of projects is devoted to the development of nuclear power, which is anticipated to cover a decisive portion of additional energy needs. Nuclear power engineering should help gradully phase out both oil and natural gas, particularly in heat generation; this ought to contribute significantly towards reducing the demands for imported high-grade fuels.

(c) The third group of projects is geared toward rationalization of energy and consumption. These efforts are estimated to permit relative energy savings of 11 mtce in 1980 and over 22 mtce in 1990.

Coal Mining

Currently roughly 124 million tons of coal are mined per year; the targets for 1985 and 1990 are 126-128 and 130 million tons, respectively. Planned annual outputs differ per type of coal. Exploitation of brown coal and lignite is envisaged to rise from currently 96 million tons to 100 million tons per year; whereas hard coal is expected to stay at approximately the present rate of about 28 million tons.

Besides minor deposits in Central and Southern Slovakia and Southern Moravia, the main base of brown coal mining is located at the Ore Mountains (Krušnéhory) range in North and North-West Bohemia. Nearly half of Czechoslovakia's geological reserves are deposited in this region, that is, mainly in the Most and Sokolov coal basins. The two districts will continue to be the fuel base and backbone of Czechoslovak power engineering for the next 30 to 40 years.

Past and current coal production figures indicate that the intensity of exploitation in these regions has been enormous. Between World War II and 1975 the North Bohemian (Most) and North West Bohemian (Sokolov) coal districts turned out 1185 and 407 million tons of coal, respectively, totaling 1590 million tons. Nearly 80% of the coal was brought out by opencast mining. In the same period, $3.1 \cdot 10^9 m^3$ of overburden was removed at an average stripping factor of 2.45 m^3/ton. While in the Most district coal exploitation increased 5.5 times the volume of stripped overburden rose 16 times, partly because of enhanced opencast mining but mainly because of ever greater mining depths (Table 3).

Table 3. Brown coal production in North Bohemia (Most district), 1945-1975.

	Production (Gt)	Increase (%)
Total	1.185	
Coal		550
Overburden		1600

Development of opencast mining technology has facilitated the exploitation of coal reserves that cannot be mined underground. There has been a gradual transition towards open-pit mining in areas with greater seam depths, where conditions for mining activities are more complex and where the overburden thickness may be as much as 200 m.

This transition to more complicated mining conditions requires new equipment that is capable of handling substantially higher outputs in extraction, distribution, and material transportation. High capacity excavators and overburden spreaders have contributed to raise the overall productivity per man shift from 7.4 tons in 1960 to about 16 tons in the period of the Sixth Five-Year Plan (1976-1980).

The first high-performance technological complex of this kind (TC-1) consisted of an excavator, belt conveyors, and an overburden spreader featuring a theoretical output of 1500 m^3 per hour. The output was raised to 2500 and 5000 m^3 per hour in the subsequent TC-2 generations, and to 10,000 m^3 for the commissioned TC-3.

What this entails in terms of equipment and investments is best illustrated by an example. To meet the planned production targets in the coal district considered, new production capacities totaling more than 50 million tons per year, will have to be built in the next 15 years; some 60 large-size excavators and overburden spreaders will be needed, and 270 km of long-distance belt conveyors with belt widths greater than 2000 mm will have to be provided during the next two five-year plans.

Another important prerequisite is adequate transportation capacity for shipping the coal from the mining districts elsewhere. Although most of the coal produced is steam coal for power generation in thermal power stations that are situated in the coal district--and which receive the coal directly via conveyers, trucks, or railroad sidings--the amounts of coal transported by the Czechoslovak National Railroads continue to grow considerably. The overall volume of coal moved by rail is now 33 million tons per year and will be stepped up to 45 million by 1990. This enormous burden on the national railway system requires extensive reconstruction and other measures lest transportation should become a bottleneck of the expanding mining operations.

Development of the coal district is complicated by the necessity for "induced" projects; the need for infrastructural development arises because mining operations are increasingly though gradually being transferred to regions where abolished mines must be replaced; a particular problem is the relocation of communication links.

As for hard coal, the annual production rate will remain fairly unchanged at approximately 28 million tons. Extraction will be much more difficult, however, with the coal reserves in geologically favorable locations being largely exhausted. This implies high investments and a preference for mines in new locations. The "Darkov" mine in the classical mining section of the Ostrava-Karviná district is a case in point. This new mine under construction is expected to have a daily output of up to 20,000 tons. Upon completion in 1990 it will take over the output from the "Ninth of May" mine and exploit the coal reserves of the present "May Day" mine. Further investment projects are about to start in other new mining districts, such as Příbor-East and Frenštát-Trojanovice. Major efforts at developing the bottom part of the Karviná "saddle strata" seams involve an area of about 60 km^2. Exploratory borehole estimates indicate an annual production potential of up to 4 million tons of high-grade coking coal.

However, exploration results obtained imply that exploitation would have to be carried out under conditions so far unprecedented in Czechoslovak mining practice. This is due to the very complicated geological structure of the strata, critical depths of future workings, considerable influx of methane, high temperature of surrounding rocks, substantial water inrush, "heavy" roof layers, increased inflammability of coal, and coal and gas outbursts.

Other locations are operated by the Association of Kladno hard coal mines in the districts of Kladno, West Bohemia, East Bohemia, and Rosice, Southern Moravia. There reserves are fairly exhausted due to past intensive exploitation, and further production cutbacks are envisaged for the period of 1981-90.

However, in the East Bohemian district, i.e., in the area of the Nejedlý and Stakhanov mines, it appears that production figures may be maintained still beyond the year 2000. The former mine, with some coking coal seams, is being reconstructed for providing up to 600,000 tons annual output by 1990. Geological exploration in new sectors of the Stakhanov mine area has ascertained that the total volume of exploitable reserves justifies extensive reconstruction. According to a two-stage reconstruction plan, annual output will first amount to 600,000 tons of coal, and later, in 1990, to 1.2 million.

Another promising region of the Kladno Association is the Slaný coal basin with four seams at depths of 1000-1200 m, containing over 300 million tons of geological resources, some 170 million of which are reserves. A new mine in the Slaný coal basin may be constructed in the period of the Seventh Five-Year Plan, with production to start about 1995 and full capacity amounting to 2.5 million tons per year. Even here, the highly complicated mining and geological conditions presuppose a considerable amount of R&D for safe and effective mining. Problems arise mainly for hydrogeological reasons: waters are saturated with CO_2 and H_2S at pressures of 3-8 MPa, seams are jeopardized by rock percussions, working depths reach to 1000 and 1200 m, and temperatures exceed 35°C. These conditions require new shaft sinking techniques, coal extraction methods for greater depths, pumping and treatment of salt waters, and underground air conditioning.

As can be seen from the above, this expansion of output from coal mining requires higher investments now than in the foregoing period. Capital requirements are estimated to be about $40 \cdot 10^9$ Czechoslovak crowns in both the Seventh and Eighth Five-Year Plan periods.

Power Engineering

The future development of Czechoslovak power engineering will depend upon a gradual increase in energy production by nuclear power stations. The construction of further thermal power stations is ruled out by the amounts of coal reserves available. The last major thermal power plants to be completed are Prunerov II and Melnik III. Thus nuclear power will have to step in, which is expected to grow from 4.5 TWh in 1980 to about 40 TWh in 1990, fully covering the incremental electric power consumption that is anticipated for that period.

The country's nuclear power capacity is being built up consistently. The 880 MW nuclear power station V-1 at Jaslovské Bohunice operates reliably, and another station of the same capacity is under construction there. A 1760 MW power plant is underway at Dukovany. Other pending projects involve four 440 MW blocks for a power station at Mochovce and the first 1000 MW block to be set up at Temelin.

Nuclear power plants will mainly be used to supply industrial heat. So far, the construction of nuclear power cogeneration plants and, possibly, of nuclear heat generation plants providing heat for large cities is at the planning stage.

For the planned development of nuclear power engineering the country will be able to rely on adequate domestic uranium supplies and, above all, on its close cooperation with the Soviet Union. The nuclear program will be mostly based on equipment made in Czechoslovakia, which other than for domestic purposes will also be exported to other socialist countries.

Another important branch of Czechoslovak power engineering is hydropower. The output currently attainable is 1.2 GW, which is slightly more than half of what is assumed to be available upon completion of the pumped storage power stations Cierny Váh and Dlouhé Stráně and the Danube hydropower station. Furthermore, small-scale hydropower stations of up to 10 MW capacity may add as much as 1.7 TWh per year.

Hydrocarbon Production

In the fuels and energy balance gas is gaining importance. Most natural gas is imported from the Soviet Union. 1980 imports were 7.7. Gm^3, and a moderate growth is expected for the period of the Seventh Five-Year Plan (1981-1985).

With natural gas production growing from currently 1 Gm^3 to about 1.75 Gm^3 in 1990, domestic deposits do not play a prominent role. However, these gas fields are regarded as supplementary source; they are used to cover seasonal consumption peaks and are linked to underground gas storage capacities and peak-supporting sources. They must be fully equipped technically so as to permit maximum production when needed, especially in wintertime. Storage capacity in underground facilities is planned to increase from currently 900 million m^3 to beyond $3 \cdot 10^9$ m^3 in 1990.

Gas industry expansion requires considerable capital expenditure. For 1980-1990, the amount required for building long-distance transit pipelines is nearly $10 \cdot 10^9$ Czechoslovak crowns. This is more than one third of the expenses incurred for the overall development of the gas industry including the exploitation of natural gas and oil reserves.

The oil reserves ascertained do not support any increase in domestic annual production, now about 100,000 tons. Present deposits are generally not deeper than 2-2.5 km. For an expansion, substantially greater depths of 3-6.5 km and more will have to be explored in potential new areas and formations.

Energy Costs and Rationalization

Table 4 shows the evolution of the energy energy supply structure, 1960-2000, in percent. Note that

- the emphasis is on coal exploitation
- nuclear power is tentatively assumed to reach about 20% of supply in the year 2000.

Table 4. Evolution of primary energy supply structure in Czechoslovakia (%).

Energy Source	1960	1965	1970	1975	1980*	1985	1990	2000
Solid fuels	87.4	81.3	75.0	67.6	61.9	58.3	52.5	39.8
Oil and its products	6.5	12.3	17.2	23.6	24.0	24.3	23.8	20.3
Natural gas	2.6	1.4	3.2	5.1	9.9	10.4	11.4	14.9
Nuclear energy	-	-	-	0.1	0.9	4.6	9.3	20.0
Hydroelectric power	2.0	2.8	1.7	1.4	1.6	1.1	1.4	1.2
Other electric power, incl. imports	1.5	2.2	2.9	2.2	1.7	1.3	1.6	3.8
Total	100	100	100	100	100	100	100	100

*Preliminary.

Even this very brief characterization of the energy supply structure is indicative of the kind and scope of problems involved in providing adequate fuel and energy.

A main problem is cost. The specific costs of providing energy (i.e., the cost per unit of primary energy) have been found to grow progressively with the amount of energy involved, i.e., to be an exponential function of the amount of energy with positive parameters:

$$\left.\begin{array}{l}\nu(E) = ae^{bE} \\ (a,b>0)\end{array}\right\} \longrightarrow \left\{\begin{array}{l}N'(E)>0 \\ N''(E)>0\end{array}\right.$$

with

E amount of energy resources, tce;
N(E) cost of energy in Czechoslovak crowns for E.

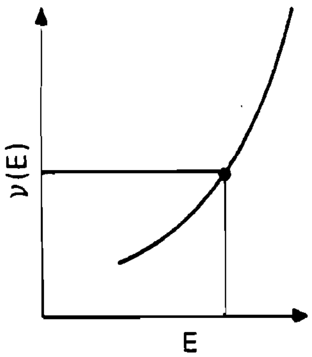


Figure 1. Specific costs of energy.

This relationship holds not only for total costs but analogically also for capital expenditure, hard currency requirements, manpower, environmental damage, etc.

These parameters or the value of any one of them could quite easily become prohibitive unless the requirements for energy can be kept at a tolerable level. Thus there is an immediate and vital need for rationalizing the use and consumption of fuels and energy. This is the third main line of target program activities described above.

The position of the Czechoslovak power engineering and fuel economy must be made quite clear in this context. It is defined as follows:

In order for the national economy to develop smoothly it is indispensable that the considerable reserve potential that exists be exploited in a sufficiently broad manner permitting a consistent rationalization of the use and consumption of *fuels and energy. This is and will remain one of the fundamental issues of the country's overall economy.*

The main problem evolves from the fact that Czechoslovakia's national primary energy consumption tends to be too high. One cannot continuously put up with a situation as shown in Table 5, where more energy is spent per person than in other advanced countries that generate a higher GNP/cap at a lower per-capita energy consumption. This fact is not just a consequence of Czechoslovakia's primary energy structure, which is characterized by a high share of solid fuels resulting in very high conversion losses.

Table 5. Per capita energy consumption in various countries as compared to that of Czechoslovakia, 1980 (tce).

Country	tce/cap	Index
C.S.S.R.	*6.7*	*100*
F.R.G.	6.2	93
Netherlands	6.1	91
U.K.	5.8	87
Japan	4.8	67

In recent years, the country has seen a gradual reduction in energy consumption in terms of primary energy per unit of national income. Compare Table 6 for the periods 1965-1975 and thereafter. Specific energy consumption decreased at a relatively faster pace in the early period than over the total period under consideration. This was the time when the energy supply structure came to change rapidly in favor of liquid and gaseous fuels, the latter rising from about 13.0% to 30%. Though specific energy consumption keeps going down even after 1975 it does so at a much slower rate, as is indicated by the growing values of specific energy consumption in the fifth line and the energy elasticity index in the bottom line of the table.

Accordingly, our energy consumption level is markedly higher than that of some other industrially advanced countries; assuming an energy efficiency comparable to such highly developed countries as, e.g., Japan, the difference amounts to roughly 25 to 30 mtce per year. Here, rationalizing the use and consumption of fuels and energy will be an important task. Yet changes will have to come about gradually, for the problems involved are far reaching and interlinked.

A major tool for improving energy use and for cutting national energy needs is provided by the target-oriented state program (TOSP) that is geared to the rationalization of energy use and consumption. This program consists of a variety of measures discussed elsewhere.

Table 6. Relating energy consumption and gross national product.

Parameter	1965	1970	1975	1980 (preliminary)
Gross national product (10^9 Crowns)	230.5	313.5	415	505
Primary domestic consumption (mtce)	71.9	81.2	93.1	105.1
Energy required to produce GNP (ktce/10^9 Crowns)	312	259	224	208
Energy requirement index (%)	100	83.0	71.8	66.7
Relative change of specific energy consumption per five-year-period[a] (%)	-	83.0	86.5	92.8
Flexibility factor ε	-	0.396	0.488	0.618

[a]Calculated from one five-year plan period to the next.

$$\frac{E(t_2)}{E(t_1)} = \left[\frac{D(t_2)}{D(t_1)}\right]^{\varepsilon}$$

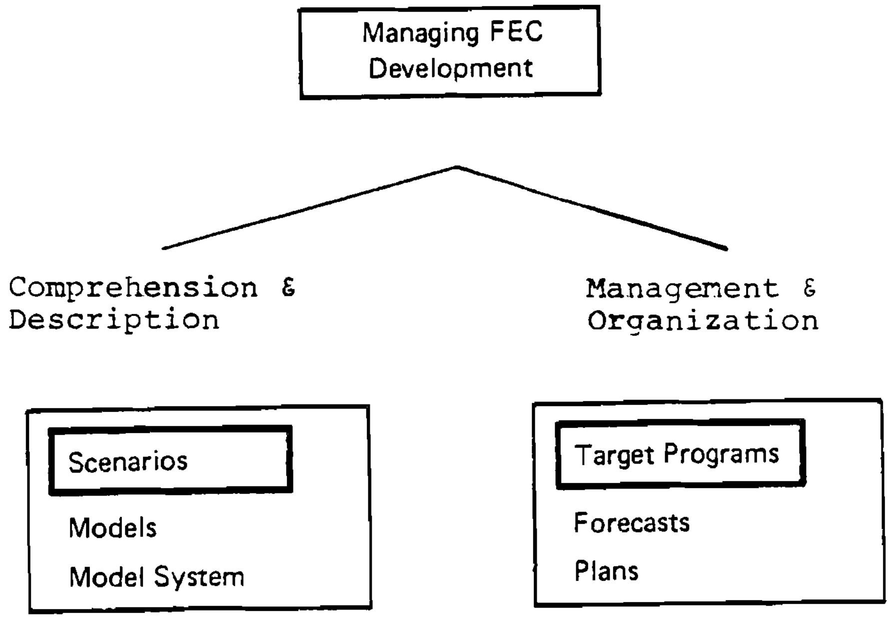
t five-year period
E(t) primary energy consumption over period t.
D(t) national product over period t.

MANAGING NATIONAL ENERGY DEVELOPMENT

This brief overview of Czechoslovakia's energy situation would be incomplete without mentioning adequate management of the fuel and energy system. Some of the problems involved are also related to the TOSPs. Typically, a country's FEC is an extensive and complex socioeconomic system. Managing and controlling such a system are very complex tasks. Such problems are dealt with by present management theory and practice all over the world, irrespective of the social and political system in question. A very good example of how such problems may be approached has been given by IIASA's Energy Systems Program. Another prominent and broadly based project is currently under way at the International Scientific Research Institute for Management Problems in Moscow.

The latter is among others aimed at the application of system-theoretical and modeling approaches for improving the scientific management of the development of the national fuel and energy system. In this context, also some of our approaches and results should be mentioned. In fact, I am absolutely convinced that the traditional and routine methods used in the past are no longer adequate for solving the problems under consideration. This fact alone (over and above the need for a common understanding of certain concepts in this field) necessitates a continuous and intensive exchange of results, experience, and ideas that is to go on at all levels and include all aspects and positions.

Some of the new possibilities seem to lie in an effective combination of the scenario approach with the TOSP method. By using such an approach it would be possible to link the cognitive function of scenarios with the managerial and organizational purposes of TOSPs (Figure 2).



"As regards the broad and topical question of management I will mention just two points. One of them concerns planning, which requires extensive use of the method of target programs. Such a program must be a well-founded set of measures and be backed up by accurate calculations. These measures must be oriented towards the final result, i.e., a complete solution of a given problem. It is important that the program define the stages and sequence of meeting the various tasks. Obviously, it is also necessary to have a program management system that clearly defines the personal responsibilities in every sector of work and grants the necessary rights. Without all that the program would be nothing but a list of yearned-for desires."
L.I. Brezhnev at the meeting of the Central Committee of the USSR Communist Party in October 1980.

Figure 2. Managing the development of FEC systems.

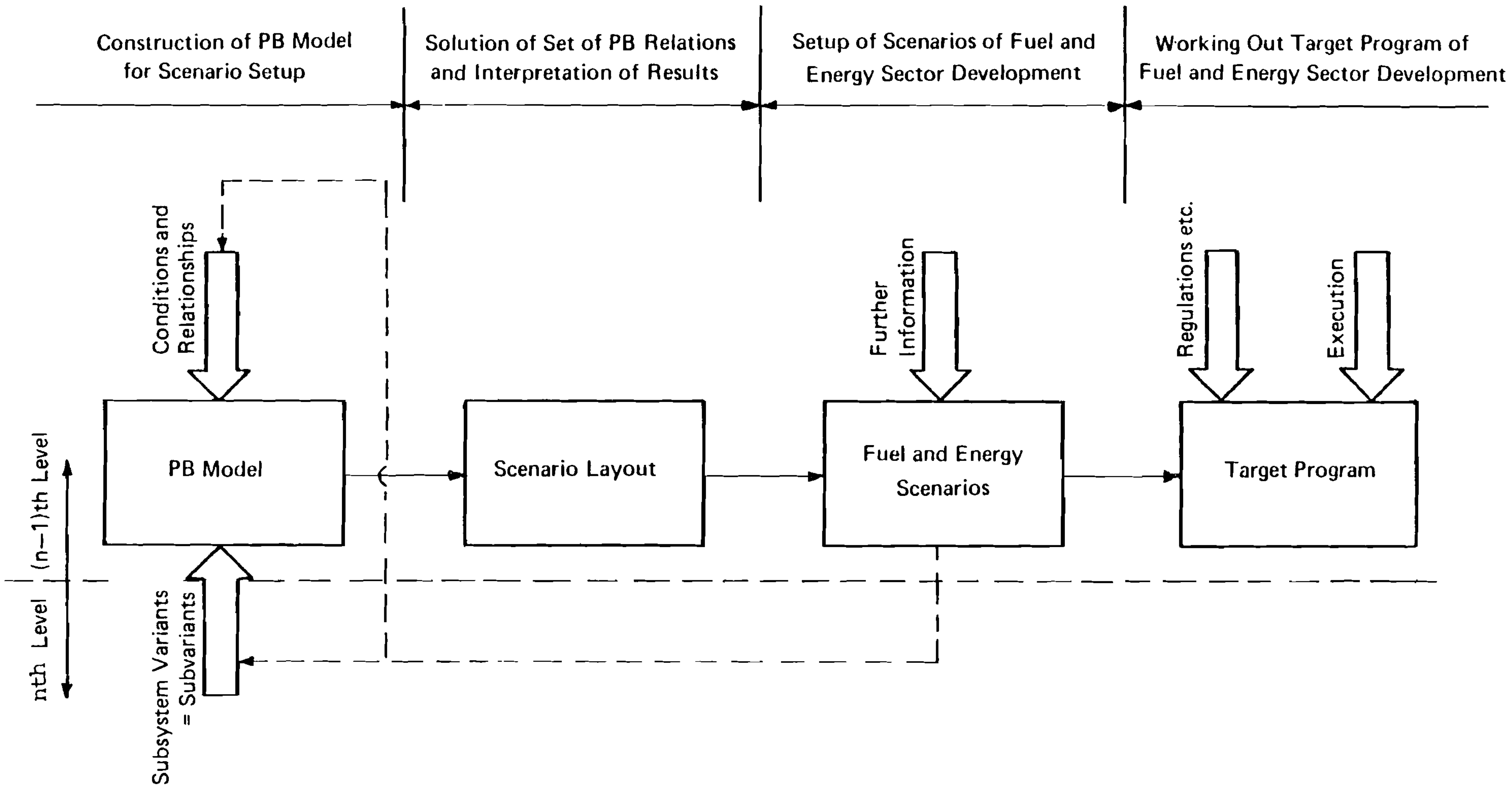


Figure 3. Schematic procedure for working out a target program with the help of scenarios.

However, working out a TOSP for such complicated systems as a country's fuel and energy sector or a part thereof is an extremely demanding task since the program must meet the categorical requirements mentioned above. It turns out that the task can be largely simplified by using suitable scenarios and effective models. Figure 3 is a rough and basic schematic representation of the procedure that can be employed for working out a target program with the help of scenarios.

Note the procedure used to set up the scenarios proper. This separate element consists of a suitable modeling procedure (i.e., a mathematical and logic modeling method) serving to construct a series of scenarios. It is also termed the scenario layout since it determines the kind of set up chosen for the scenario series; the set covers a region of system development possibilities which has been reasonably delimited beforehand. In this way the scenario selection should be improved, the degree of arbitrary selection be reduced,and the communication of the scenarios be enhanced eventually. However, the procedure is to be refined further in conjunction with other approaches. Significant experience will be derived from applications with respect to long-term development up to the year 2000.

If such and other lines in the development of fuels and power engineering can be pursued in a creative atmosphere of national and international cooperation they will be of benefit for society as a whole and thus contribute to peace throughout the world.

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