SYSTEMS ANALYSIS OF ENERGY PROCESSES

Al. A. Makarov
The Energy Research Institute, Russian Academy of Sciences, Russia

Keywords: System analysis; energy development; long term; premises and means; temporal limits; energy modeling; dynamic; uncertainty; energy-economy interconnections; energy supply system; resources; R&D strategies.

Contents

Summary

Systems approach has already been widely acknowledged as the principal methodological basis for studying possible patterns of social and economic development, particularly, energy development. It plays a particularly important role in the so-called 'normative' forecasting, aiming not only at projecting possible scenarios of future development but also choosing a preferable one among them with regard to some criteria. However, in spite of the appreciation of the philosophy of systems approach**,** its initial premises and the resulting requirements to methods**,** as well as the temporal limits of its applicability have not been defined properly yet. Below an attempt is made to fill this gap.

1. Introduction

The principal theses underlying most studies carried out until recently on energy systems assumed:

- the existence of objective regularities in the development of the phenomena under consideration;
- the possibility of quantifying those regularities or, at least, of finding out quantitative measures for their visible images;
- the validity of the past regularities or their quantitative images in the future.

These theses can be observed most clearly in the simplest case - when a forecast offers an extrapolation of the past trends found out by means of analysis of statistical data about forecasting the phenomenon. The first thesis from those said above seems to be correct **-** energy as one of the most essential components of the productive forces is developing according to objective tendencies inherent in them. However, the contents of those tendencies, and, all the more**,** their quantitative characteristics, can hardly be explored, and their visible quantitative images are far too multiple and heterogeneous to validate the second thesis. Finally, the third thesis can be accepted only for making short-range forecasts, and is evidently inadequate for long-term assessment of energy development. Over the last twenty-thirty years a new approach, system analysis, appeared and became the basis for investigating and forecasting complex systems.

2. Premises and means of the systems approach to energy development

2.1 Premises of the Systems Approach

Systems analysis is based on premises different from those applied in the traditional approach. Certainly, it rests on past experience and employs a comprehensive analysis of trends of the past development just as the traditional approach does. However, in this case external and internal relationships of the system (especially those of production) which are observed more easily and therefore are more open for study, become the principal subject of analysis. Exposure of those relationships and quantitative estimation of their parameters provides the ground to project development of the system.
Thus the systems approach assumes:

1. possibility of exploring external and internal relationships of the systems studied,
2. visibility of those relationships and their parameters, and
3. possibility of quantitative estimation of prospective values of the technological parameters characterizing the relationships of interest.

The premises mentioned above express the necessary and, as it is believed, sufficient conditions for building a model (formal or partly mental) for the study of a system and serve currently as the principal tool of systems analysis. But they do not imply satisfying the extremely important - and frequently forgotten - condition of adequacy of a model and the modeled system that provides right use of models. As no formal methods of model verification exist yet, modeling continues to be a kind of art accessible only to experts in systems analysis, namely those who are capable of selecting the essential relationships of the system from their innumerable number, and of finding the means to check whether me choice was right. One should not underestimate the role of that factor in systems approach in forecasting as well as the resulting 'humanization' or 'subjectivisation' of conclusions. It would he incorrect to suppose that systems analysis allows removal of professional limits to the extent, that an energy forecast can be worked out, say, by a mathematician or an economist with the same success as by an energy expert.

- Taking into account the above reservation, one can consider the first premise of the systems approach to energy forecasting as sufficiently feasible. The second requirement that implies making models visible and matching modern computers is also usually met by reasonable aggregation of the system's relationships- The major difficulties of systems analysis of energy development are connected with satisfying the third premise demanding proper provisions of information. The various kinds of technological parameters which make overwhelming share of input data necessary for systems forecasting of energy might be subdivided into the following three groups with regard to difficulties in evaluating them:

- Parameters of existing and similar new energy technologies, evaluation of which does not offer any principal difficulties.
- Parameters of new energy technologies or of existing ones applied under essentially new conditions (like oil production from deep offshore). The values of such parameters are estimated on the basis of technological, geological, and other projections made by specialists in connected areas with knowledge of the structure of new technologies and analogs for their main components. Thus, this part of the work on energy forecasting also cannot be made without participation of a wide group of energy experts - not system analysts but technologists.
- Aggregated parameters characterizing complex connections of energy with other sectors of the economy, above all, connections with energy demand. The pervading character of energy makes those connections so fractional and numerous that their detailed modeling is hardly possible and, what is more, harmful because in most cases it could break the consistency of the level of detail throughout the model. Therefore for purposes of long-range forecasting both straight and back energy-economy connections should be modeled in an aggregated way. But this, in turn, demands a determination of future values of a great number of aggregated indices of economic development the technological basis of which is considerably unrecognizable. So far only one way exists of evaluation of such economic indices namely the way of extrapolation of their past trends for the future, that is of making use of traditional (not systems) methods of energy forecasting.

The paradox of systems approach to energy forecasting lies in the fact that at some phase at its implementation the necessity has appeared to use extrapolation methods together with their controversial premises. In other words, straightforward application of systems analysis to development of real systems is impossible, as in such a case one would have to study the whole set of interfaces inherent in the economic and social environments. On the other hand, the necessity to distinguish the scope of the studied system inevitably demands outside forecasting of its broken external connections involving extrapolation methods. This paradox seems to discredit the systems approach as one just adding its own hard-met conditions to ones of the traditional approach.

In fact, however, that is not the case if systems analysis is used intelligently. On the one hand, the deeper the modeling of external connections of the system expands outside it the less the errors of exogenous parameters definition affecting the results of forecasting. For example, the results of projection of the production structure of energy supply systems show much less accuracy if demand for energy, and capital and material resources available for energy development are given exogenously than in the case when a combination of energy and economic intersector models is applied with exogenous setting to the normatives of input-output matrices. In other words, the farther we move the line of exogenously given parameters from projected ones (that is the fuller the systems approach is realized) the less the possible errors in definition of exogenous parameters and, hence, shortcomings of the traditional methods, influence the results.

On the other hand, the errors of forecasting become smaller if a given number of exogenous parameters are greater because the impact of each of them on the final results becomes weaker. Obviously, the latter is valid only if exogenous parameters are mutually independent and shows about equal impacts on the results. Coming back to the example given above it means that forecasting of the production structure of the energy supply system (ESS) on the basis of exogenously given demand for energy is dangerous as the parameters of energy demand are highly dependent on each other and, together, they influence the results on ESS development to a very high extent (almost definitely). As a result, all the shortcomings of traditional ways of energy demand projection will be inherent in the systems approach to ESS development. On the contrary, combining an energy model and an intersector model of the economy replaces exogenous energy demand assessment (and exogenous assessment of values of economic resources directed to the energy development) by projection of a great number of mostly independent coefficients of input-output matrices of about equal potential impacts on results. Even substantial errors in definition of future values of those coefficients lead to comparatively small total impact on results, thanks to the effect of their mutual compensation. For example, if economic and energy development is described by linear models which is currently the practice, then the errors in outputs appear to be a 2-5 times less than the errors in inputs.

Thus a skillful approximation of external connections of the system together with straightforward modeling of major aspects lets us minimize - but not remove - the limitations of the traditional methods of forecasting and take the advantages of systems approach. But it should be stressed once again that the high professionalism of forecast-makers who combine general and specific knowledge of the system with mathematical background and sufficient understanding of higher and adjacent systems is an indispensable condition for success.

-
-
-

Bibliography

Burkov V., Irikov V., and Makarova A. (1980). Assessment of Scientific and Technological Progress in the Approach to Energy Development Forecasting. Proceedings of IIASA/IFAC Symposium on Modeling of Large-Scale Energy Systems, Laxenburg, Austria, p.87-98 [Models for Energy Resources Forecasting and Optimization, Economics and Mathematical Methods is described in this paper.]

Eskin V., Rudkevich A., and Lukyanov A. (1989) Petroleum in the Structure of Energy Industry: the Scientific Basis of Long-term Forecasting. Moscow: Nauka, 268 pp. [Scientific Approaches and Models of Energy Development is given in this book.].

Koneva O. (1997) Imitation Modeling of Economy Systems. Irkutsk:. IGU, 230 pp. [Different Types of Economy and Energy Models and System Approach to Development of these Models are described in this book]

Zimin I., and Propoi A. (1980). Dynamic Linear Programming Models of Energy, Resources and Economy – Developing Systems. The International Institute for Applied Systems Analysis, Laxenburg, Austria, 48 pp. [Models of Energy-Economy Interactions for Long-term Energy Development is the theme of this paper.]

Biographical Sketch

Al. A. Makarov - Corresponding member of Russian Academy of Sciences; Director of the Energy Research Institute, Member of International Association of Energetic Economists (IAEE) and Moscow International Energy Club (MIEC); author of more then 200 books and articles on problems of energy systems studies. Among these are the following:

1. Methods of Energy Study and Optimization. Nauka, Novosibirsk, 1973

2. Models for Energy Development and Coordination of Designees. SEI, Irkutsk, 1984

3. The World Energy and Euro-Asian Space, M. Energoatomizdat, 1998