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Effective Approaches to Energy Planning and Classification of Energy Systems Models

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ABSTRACT

A balance between energy supply and demand is one of the challenges faced by policy makers. In fact, the main objective of energy planning is to achieve this balance. Energy models can be used for supply and demand future planning of a country or region. In most situations, these methods focus on economic development, energy policy, selection of appropriate resources and technologies for the future and investing in these technologies. This paper discusses the definitions of energy planning and classifies models of energy systems according to various approaches. The paper concludes that overall energy planning requires a balance between supply and demand of energy. However, achieving this balance is possible with the coordination of all energy sectors, proper development and implementation of energy policies and finally guidance and help to the consumer to select the best sources.

Keywords: Energy Planning, Energy Systems Modeling, Energy Management
JEL Classifications: O13, Q4

1. INTRODUCTION

As one of the essential needs of humanity, energy has always been one of the most influential factors in economic, social, technical and environmental sectors. Hence, achieving an appropriate situation in this area and having proper planning adapted to specific conditions and characteristics of each country are considered two of the priorities of the governments. In recent decades, due to increasing demand for energy and turning to renewable resources instead of fossil fuels various models and methods in predicting and determining the appropriate share of required energy fuels have been developed.

According to the latest balance sheet published in Iran, in 2012, the primary energy production was equivalent to 2,219.1 million barrels of crude oil, of which only 0.5% was allocated to wind, solar, hydro and nuclear energies, 0.4% to the combustible renewable and the rest, i.e., 99.1%, to the fossil resources. Moreover, the final energy consumption mentioned is equivalent to 1,058.6 million barrels of oil 0.71% and 9.93% are provided by combustible renewable resources and by the electricity, respectively. Overall, per capita consumption of natural gas and crude oil and their petroleum products are 6 and 1.6 times as much as the global average, while the per capita consumption of renewable resources, coal and electricity is less than that of the global average. The per capita CO_2 emissions in 2010, was about 4.9 tons in the world while it was 7.7 tons/year in Iran (Office Macro, 2013, The World Bank).

With regard to these statistics, high energy consumption in Iran and consequently emissions from the combustion of fossil fuels need more attention to be paid to the replacement of conventional energy sources and fossil fuels than ever before. Construction and operation of a 29.9 MW wind power and 1.6 MW biomass power plant to generate electricity are activities that have taken place in the renewable resources sector in Iran. Of course, other projects and feasibility studies are in the process of obtaining the necessary permits, too. Although several projects in various sectors of renewable sources in the operation have been carried out, their low share cannot meet the demand of the growing population. In addition, the incidence of economic fluctuations affecting fossil resources, population growth and increasing energy demand and raising awareness about the negative effects of fossil fuels on the environment and human health, have made the use of renewable resources the focus of attention. Renewable energy sources have a higher price stability because they are less vulnerable to price fluctuations; Therefore they reduce dependence on resources such as oil, and they will ultimately protect the environment. Finally, taking the social and economic well-being of society into account, the quality of energy at the point of consumption, growth in less developed regions and similar cases make the utilization of renewable resources more important.

2. THE DEFINITION OF ENERGY PLANNING

Despite different definitions of energy planning, all these definitions focus on common points. According to a survey on energy planning and related definitions, a good energy plan has been introduced as a program based on rigorous research on issues related to energy supply and demand, energy prices, technology supply and demand, population growth, environmental, social, technological success in harnessing the energy and influence the political situation of a country (Ravita et al., 2014). Some definitions of energy planning by other researchers are as follows:

- Energy planning is an optimal combination of energy sources to satisfy demand (Thery and Zarate, 2009)
- Meeting projected energy demand during a given period, by taking the political, social and environmental considerations into account as well as data collected from previous energy plans are the basis for energy planning (Cormio et al., 2003)
- Energy planning includes finding a set of resources and energy conversion equipment to meet the energy demand in a way that is desirable (Hiremath et al., 2007)
- Ensuring the supply as primary goal of energy planning is achievable by careful management of natural resources, diversification of energy sources to reduce energy imports and rational use of energy (Kleinpeter, 1995)
- The energy planning goal is to determine the optimal mixture of energy sources to meet the energy demand (Mourmouris and Potolias, 2013).

The need to meet the demand in a way desired is the most common point in these definitions. Furthermore, considering the amount of supply and planning and rightful management of resources in terms of criteria affecting energy sources is mentioned in most definitions. With regard to the common points, we can see that overall energy planning requires a balance between demand and supply of energy. In fact, to achieve this balance is possible if all the energy sectors are coordinated together, and in addition to correct formulation and implementation of energy policies, help the consumer in better use of resource.

3. ENERGY SYSTEMS MODELS CLASSIFICATION

Energy modeling dates back to the early 1960s; however, due to the first oil crisis in the world in 1973, the development of these models was followed more seriously (Jebaraj, 2006). Since then, many methods for planning energy systems with different categories in various fields have been created; however, none of them can be the best classification proposed. In fact, a comprehensive classification scheme or program can provide a good understanding of the differences and similarities between the energy models and can facilitate the process of selecting the most appropriate model to use in the desired position or location. However, to choose a suitable model, study and overview on different methods of classification can be useful. In the following section, energy models are classified based on 6 different approaches, and the specifications and features of each approach are discussed.

3.1. The First Approach: Classification Based on Criteria Related to Models

Each model is a simplified form of the reality. Models of energy systems are designed and created based on different purposes in order to use in different situations. Thus, according to the objectives, assumptions and conditions of applying any model will be effective to classify them. At the moment, there are different criteria to classify energy models; an example of a classification distinguishes three important ways to differentiate energy models; namely, the purpose of the models, their structure, and their external or input assumptions (Hourcade et al., 1996). Another uses six dimensions to classify energy models; (1) top-down versus bottom-up, (2) time horizon, (3) sectoral coverage, (4) optimization versus simulation techniques, (5) level of aggregation, and finally (6) geographic coverage, trade, and leakage (Grubb et al., 1993). In addition to the above, other criteria such as mathematical techniques, the degree of complexity of the model and the flexibility of the model were considered for classification. Finally, general criteria for the classification of different models are as follows (Van Beck, 1999):

1. Purposes of energy models: General and specific purposes
2. The model structure: Internal and external assumptions
3. The analytical approach: Top-down versus bottom-up
4. The underlying methodology: Econometric, macro-economic, economic equilibrium, optimization, simulation, spreadsheet (tool boxes), back-casting and multi-criteria models
5. The mathematical approach: Linear (LP), mixed integer (MIP) and dynamic programming
6. Geographical coverage: Global, regional, national, local, or project
7. Sectoral coverage
8. The time horizon: Short, medium, and long term
9. Data requirements: Quantitative, qualitative, synthetic.

3.2. The Second Approach: Classification of Jebaraj

In a comprehensive study by Jebaraj in 2006, all the energy models had been studied by that time. Today, his proposed classification is used as a comprehensive approach to the energy models. That is why the proposed approach has been introduced individually and as an integrated approach to energy classification models. In recent years, several papers have been presented on the basis of this approach. Jebaraj has studied numerous researches that had been published in different years, and based on the existing review articles, he has provided the following categories:

1. Energy planning models: These models are designed to create an integrated energy model to consider all sources of energy
2. Energy supply-demand models: These models include models of energy supply, energy demand and a combination of supply and demand as hybrid models

3. Forecasting models: These models are formulated based on different variables such as population, income, prices, growth factors and technology. The forecasting models' purpose is to determine the distribution patterns of energy. Both fossil fuels and renewable energy resources are considered in these models
4. Optimization models: In order to allocate energy demand for each of the renewable resources, formulation of optimization models is done
5. Energy models based on neural networks: During the time, using artificial intelligence technologies is more common to solve complex scientific problems in various sectors. The reasons are their being reasonable, flexible and self-explanatory systems based on artificial intelligence
6. Emission reduction models: The destructive effects of pollutants and greenhouse gases caused by fossil fuels leading to develop some models to assess the total amount of these pollutants and the use of renewable sources instead of fossil fuels (Jebaraj, 2006).

3.3. The Third Approach: Classification Based on Analytical Approach of Models

Different types of energy models, based on their analytical or conceptual framework, include top-down approach, bottom-up approach and integrated approach that is the combination of the two main approaches. The difference between the two groups is very interesting because they provide different results for one question. In fact, the difference in the results arises from the method or style of decisions, technology adoption and behavior of markets and economic institutions in a given period (Van Beck, 1999). Table 1 compares the characteristics of two main approaches.

Top-down models including input-output models, econometric models, computable general equilibrium models and systems dynamic, as well as partial equilibrium models, optimization models, simulation models and multi-agent models are as bottom-up models (Herbst et al., 2012).

To overcome the weaknesses and limitations such as lack of technological detail, delivering rather generalized information on the top-down models and lack of macro-effects of the presumed technological change on overall economic activity, structural changes, employment, and prices in bottom-up models, energy modelling is currently moving in the direction of hybrid energy system modelling combining at least one macroeconomic model with at least one set of bottom-up models for each final energy sector and the conversion sector. A high-quality hybrid model system should incorporate at least three properties:

1. Technological explicitness
2. Microeconomic realism
3. Macroeconomic completeness.

In addition, considering important issues like the structural changes (inter-sectoral and intra-sectoral) and technological progress require more attention (Herbst et al., 2012).

3.4. The Fourth Approach: Classification as Supply-demand Perspective

One of the main tasks of the energy sector is meeting energy demand in various sectors. Energy demand is influenced by social, economic, technological and technical factors; therefore, supply of energy needs the development of energy system modeling. Energy demand models like other models of energy can be classified by criteria such as objectives, assumptions, technological change and the description of environment. In the general case, the models are grouped in econometric approach, optimization approach and forecasting approach (Ravita et al., 2014). Energy forecasting as one of the most widely used areas in energy demand has several approaches. Types of energy demand forecasting models are: Time series models, regression models, econometric models, decomposition models, cointegration models, ARIMA models, Artificial systems like experts systems and ANN models, grey prediction models, input-output models, fuzzy logic/genetic algorithm models, integrated models like autoregressive, support vector regression and Particle swarm optimization models, and Bottom up models like MARKAL/TIMES/LEAP (Suganthi and Samuel, 2012).

In order to meet the energy needs of the different sectors, supply systems will be created. In fact, the supply of useful energy is possible through utilization of primary energy and by diverse

Table 1: Characteristics of top-down and bottom-up approaches (Van Beck, 1999)

Top-down models	Bottom-up models
Use an "economic approach"	Use an "engineering approach"
Give pessimistic estimates on "best" performance	Give optimistic estimates on "best" performance
Cannot explicitly represent technologies	Allow for detailed description of technologies
Reflect available technologies adopted by the market	Reflect technical potential
The "most efficient" technologies are given by the production frontier (which is set by market behavior)	Efficient technologies can lie beyond the economic production frontier suggested by market behavior
Use aggregated data for predicting purposes	Use disaggregated data for exploring purposes
Are based on observed market behavior	Are independent of observed market behavior
Disregard the technically most efficient technologies available, thus underestimating the potential for efficiency improvements	Disregard market thresholds (hidden costs and other constraints), thus overestimating the potential for efficiency improvements
Determine energy demand through aggregate economic indices (GNP, price elasticities), but vary in addressing energy supply	Represent supply technologies in detail using disaggregated data, but vary in addressing energy consumption
Endogenize behavioral relationships	Assess costs of technological options directly
Assume there are no discontinuities in historical trends	Assume interactions between energy sector and other sectors is negligible

energy conversion technologies. Other supply models are based on three general approaches including econometrics, optimization and forecasting, as well as the criteria mentioned in the first approach of this study. Most popular energy supply models include MARKAL, TIMES, EFOM, WASP, JASP, MESSAGE, IDEAS, RET screen, LEAP, NPEP, MESAP, NEMS and energy 2020. These models have been developed by organizations in different parts of the world. All models offer the final consumption of energy or the amount of energy required to estimate the energy demand. Therefore, the types of input and output data are mentioned in the classification of these models (Kazemi et al., 2013). Finally, it can be concluded that energy demand models only consider the demand for each of the sectors. In contrast, energy supply models simulate the demand as a predicted value. In order to obtain a better result, by extracting the positive characteristics of each group, the integrated model of supply and demand is used (Kleinpeter, 1995).

3.5. Fifth Approach: Classification as Developing Countries' Perspective

Model selection in developing countries should be based on the specific characteristics of such countries. Often (especially in econometric and optimization models) standard models for energy systems do not consider enough features and problems of developing countries (Bhattacharyya and Timilsina, 2010). As most of these models have been created and developed in industrial societies, they cannot meet the characteristics of traditional societies or developing countries. Although a number of models are flexible to consider some features (such as fossil energy sources in the model), often local or national models ignore these features. In general, the required data and theoretical foundation of the standard model and lack of ability in terms of the characteristics of a particular country make them inappropriate. Poor performance of electricity and fossil fuels, transition from a traditional economy to a modern economy and structural efficiency in society, economy and energy systems are the most important characteristics of developing countries, and need special attention (Urban et al., 2007). In addition to these general features, other cases like reliance on fossil energy sources, large informal sector that is sometimes bigger than the formal sector, the urban-rural division and spread of inequality and poverty, structural changes in the economy and the transition from traditional to modern life style, energy supply shortages due to poor performance of power plants, the existence of multiple economic and social barriers to investment and slow technological diffusion make energy systems in developing countries significantly different from these systems in developed countries (Bhattacharyya and Timilsina, 2010). Thus, the energy model in developing countries should be able to consider these features.

3.6. Sixth Approach: Classification in Uncertainty and Risk Conditions

Since the main aim of energy planning is to match the supply and demand for energy over a given period of time, understanding the energy system that confronts the energy supply and demand is crucial. In addition, uncertainties in any energy system and the possibility of shortage in energy resources necessitate the development of a model by taking the following into account. In order to control the uncertainty in energy planning, a range of different methods such as interval linear programming, fuzzy mathematical programming and random mathematical programming are generated. Other techniques under conditions of uncertainty are decision analysis methods Daim et al. (2013) and Scott et al. (2012). These methods are classified into three, including multi-criteria decision making technique, single-objective decision-making method and decision support system. Each of these techniques, using optimization methods, forecasting methods (including mathematical models and simulation), qualitative and in some cases life-cycle analysis technique and geographic information systems, provides results close to reality compared to other methods (Ravita et al., 2014).

4. CONCLUSION

In general, the balance between supply and demand is one of the challenges facing policy makers. If all energy sectors are coordinated with each other and energy policies are formulated and implemented correctly, it will be possible to achieve this balance, which is the main objective of energy planning. Energy models are used to plan for the future supply and demand of a country or region. Finally, in these methods, some cases such as economic activity development, energy policy, material selection, appropriate technology selection and investment on this technology will be considered.

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