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Improvement of energy demand forecasts using swarm intelligence: The case of Turkey with projections to 2025

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Abstract

The energy supply and demand should be closely monitored and revised the forecasts to take account of the progress of liberalization, energy efficiency improvements, structural changes in industry and other major factors. Medium and long-term forecasting of energy demand, which is based on realistic indicators, is a prerequisite to become an industrialized country and to have high living standards. Energy planning is not possible without a reasonable knowledge of past and present energy consumption and likely future demands. Energy demand management activities should bring the demand and supply closer to a perceived optimum. Turkey's energy demand has grown rapidly almost every year and is expected to continue growing. However, the energy demand forecasts prepared by the Turkey Ministry of Energy and Natural Resources overestimate the demand. Recently many studies are performed by researchers to forecast the energy demand of Turkey. Particle swarm optimization (PSO) technique has never been used for such a study. In this study a model is proposed, using PSO-based energy demand forecasting (PSOEDF), to forecast the energy demand of Turkey more efficiently. Although there are other indicators as well, gross domestic product (GDP), population, import and export are used as basic energy indicators of energy demand. In order to show the accuracy of the algorithm, a comparison is made with the ant colony optimization (ACO) energy demand estimation model which is developed for the same problem.

Keywords: Energy demand; Swarm intelligence; Turkey

1. Introduction

Energy transitions are the driving force for economical and technological development. Understanding long-term energy transitions and development trajectories is a great challenge in moving towards sustainable development in a globalizing world, especially for developing countries, like Turkey. Energy transitions are defined as; investments in possibly cleaner technologies to replace and expand the depreciating capital stock to meet growing energy demand. When considered a longer time horizon, significant changes in energy technologies and consumption could be observed.

Energy is generally expected to play a major role in achieving economic, social, and technological progress and to complement labor and capital in production (Ebohan, 1996; Templet, 1999). Energy use increases as more economic sectors develop and more channels of flow are opened (Templet, 1999). Global energy demand will increase 60% more from 2002 to 2030—with yearly average 1.7% (if no action is taken) (Tiris, 2005).

Development trajectories of energy can be characterized by sectoral changes in the economy (Lise and Van Montfort, 2007), population, import and export of the country. As already noted in the literature (Akarca and Long, 1980), there is a general agreement that a relationship exists between energy consumption and gross domestic product. Ebohan (1996) examined the causal directions between energy consumption and economic growth (proxied by GDP and GNP) for Nigeria and Tanzania.

As one of the basic indicators for energy demand, not only GDP is important but the structure of GDP as well.

Turkey has dynamic economic development and rapid population growth. As the Turkish economy grows, so does demand for energy. In practical terms, it means we are using energy more widely through increasingly efficient

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homes, cars, appliances and businesses. Therefore to develop and adopt efficient energy practices and technologies, is extremely important and prudent. The government should be advised to secure primary energy supplies and conversion capacity to enable the country to industrialize. The rapid growth from a low base suggests that Turkey still has to catch up with the industrialized nations in terms of economic development and industrialization.

With the beginning of planned development period in 1963, the combined demands of industrialization and urbanization in Turkey nearly tripled energy consumption in the 1960s and 1970s. The summary of primary energy production and consumption rates and GDP, with 5-year planning periods is given in Table 1. The growth rate of primary energy consumption is greater then the growth rate of primary energy production. The gap between production and consumption of primary energy gets larger for Turkey and consequently the development gap between Turkey and the industrialized nations is not closed yet. It is obvious that, the economic growth in the future will be matched by strong growth in energy demand.

Turkey is highly dependent to imports to satisfy its energy needs. Due to lack of fossil resources, Turkey's dependency level is around 70%, which may rise over 80% by 2030. By 2010, Turkey's oil demand will increase by 96%. Currently Turkey satisfies 40% of its energy needs by oil. 90% of its oil supplies are imported from the Middle East (Saudi Arabia, Iran, Iraq and Syria) and the Russian Federation. When it is compared to the European Union, Turkey depends on import more and the volatilities in the Middle East may affect Turkey more, therefore Turkey has to diversify its energy sources. In 2001, natural gas was constituting 19% of its energy needs. It will rise to 32% by 2010 while oil will be 33%. This makes Turkey highly dependent, since Turkey imports almost all of its gas supplies. Turkey's electricity demand has been growing very rapidly. It has increased from 56.8 TWh in 1990, to 118.5 TWh in 2000, with an annual average growth rate of 8.1%. The growth in electricity generation in recent years was below growth in electricity demand. Therefore, Turkey has become a certain importer of electricity since 1997. The electricity demand of Turkey is expected to increase 555.7 TWh in 2020. The installed electricity capacity has reached from 16.3 GW in 1990, to 26.1 GW in 1999, and is projected to increase to 104.9 GW in 2020.

Table 1
Growth rates for primary energy production, primary energy consumption and GDP (%)

Planning periods	GDP	Production	Consumption
1. Planning period (1963–1967)	6.6	6.9	5.5
2. Planning period (1968–1972)	6.3	1.9	7.4
3. Planning period (1973–1977)	5.2	1.9	7.3
4. Planning period (1973–1977)	1.7	2.7	3.8
5. Planning period (1979–1983)	4.7	4	6.5
6. Planning period (1985–1989)	3.5	0.9	4.4
7. Planning period (1996–2000)	3.5	1.3	4.5
8. Planning period (2001–2005)	6.7	1.2	6.1

Medium and long-term forecasting of energy demand based on realistic indicators is a prerequisite to become an industrialized country and thus to have high living standards. Overestimating the energy demand may cause redundancy in resources, while underestimating may cause series energy crises. In this study, a model which is using particle swarm optimization (PSO) (PSO-based energy demand forecasting (PSOEDF)) is proposed to forecast the energy demand of Turkey more efficiently. In the following section, a brief description of the problem and literature survey about the solution is given. In the Section 3, the concept of swarm intelligence and the basic PSO algorithm is given. Energy demand forecasting model, that is developed for Turkey case, is explained in the Section 4. Results of energy demand forecasting obtained by PSOEDF and future projections are presented in Section 5. Finally, the study is concluded in Section 6 with suggestions on future researches.

2. Literature review

The studies on energy demand forecasting of Turkey began at 1960s. The state planning organization (SPO) initiated the use of simple regression techniques for energy forecasting. Similar studies later have been continued by the Ministry of Energy and Natural Resources of Turkey (MENR). These early forecasts consistently predicted higher values than the consumptions, that actually occurred. Starting from 1984, several econometric modeling techniques have been employed for energy demand forecast. The model for analysis of energy demand (MAED) is the most commonly used technique by MENR. However, the energy demand forecasts determined by MAED still overestimates demand. Deviations from realization in the MAED applications between the year 1986 and 2000 can be seen in Fig. 1. There may be several reasons of this projection failure. Utgikar and Scott (2006) conducted a research to identify and analyze the causes of failures in energy forecasting studies.

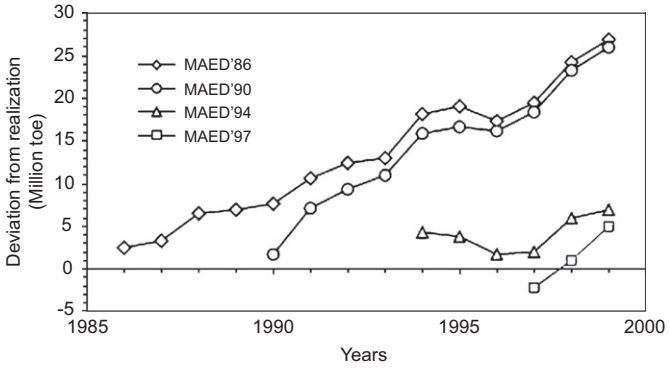

Fig. 1. Deviations from realization in the MAED applications between the years 1986 and 2000 (Ediger and Tatlidil, 2002).