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Modeling of energy consumption based on economic and demographic factors: The case of Turkey with projections

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ABSTRACT

Modeling and forecasting of the primary energy consumption (PEC) play a vital role for policy makers and related organizations in developing countries such as Turkey. In this study, Turkey's PEC is modeled by regression analysis (RA) based on population (CP) and gross domestic product (GDP). The derived model is validated by various statistical approaches such as the determination coefficient, *t*-test, *F*-test, and residual analysis. Additionally, the performance of the derived model is assessed using mean absolute percentage error (MAPE), root mean square error (RMSE) and means absolute error (MAE). Three scenarios are used for forecasting Turkey's PEC in the years 2010–2025. For each scenario, various assumptions are made considering different growth rate for CP and GDP. Using the proposed model, Turkey' PEC is forecasted under different scenarios. The results show that the proposed model can be affectively used for forecasting of Turkey's PEC. The scenarios also show that the future energy consumption of Turkey would vary between 174.65 and 203.13 Mtoe in 2025.

Contents

1. Introduction

In recent years, Turkey's energy demand has rapidly risen as a result of social and economic development. National energy policies in the country are designed to provide the required energy

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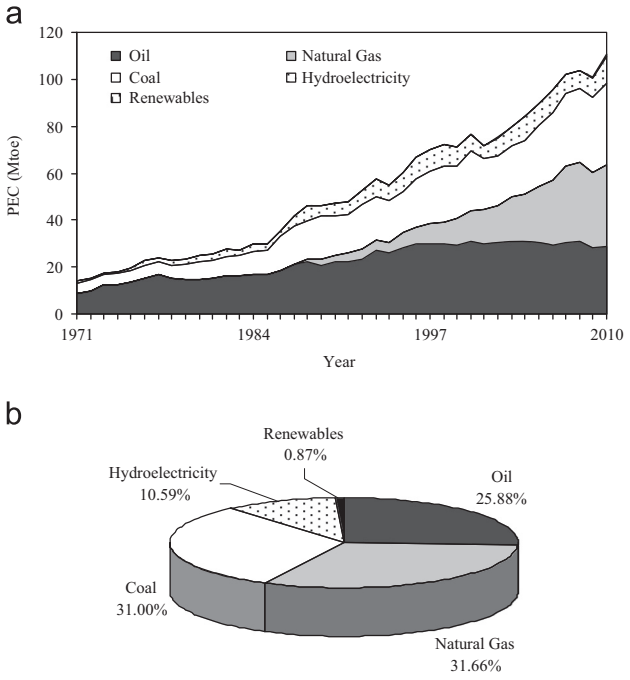

Fig. 1. Consumption of energy sources during the period 1971–2010 in Turkey (a) and the share of energy sources in the PEC for the year of 2010 (b) [3].

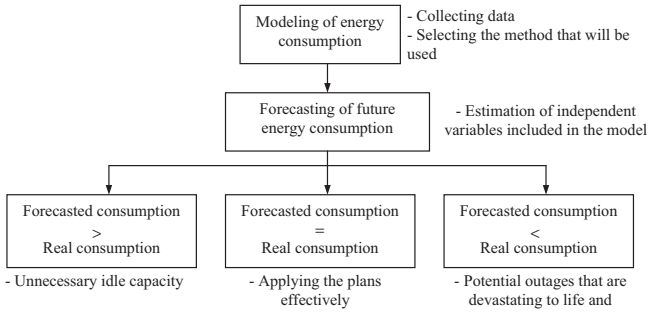

Fig. 2. Possible scenarios related to the forecasting.

on a timely, reliable, cost-effective, environment-friendly and high-quality basis so as to serve as the driving force of development and social progress [1,2]. Turkey's PEC has considerably grown since the beginning of the 1980s. It increased from 30.1 Mtoe in 1985 to 110.9 Mtoe in 2010, representing an annual growth of 5.35%. Fig. 1a and b shows Turkey's PEC during 1971–2010 and share of energy sources in the PEC for the year 2010, respectively. As can be understood from the related figures, nearly all of Turkey's PEC between 1971 and 2010 was supplied from fossil fuels. Natural gas (NG) consumption has rapidly risen in recent years while oil's share has decreased. In 1971, the oil's share of Turkey's PEC was 64.61% with no use of NG, but in 2010, oil's share decreased to 25.88% and the share of NG increase to 31.66% [3–6].

A projection of future energy consumption is a vital input to many analyses of economic, energy, and environmental policies [7–10]. For example, the decision on future energy investment requires an outlook on future energy consumption [11–13]. Underestimation of the energy consumption would lead to potential greenhouse gases; whereas overestimation would lead to unnecessary idle capacity (see Fig. 2). Therefore, it would be better to model energy consumption with a good accuracy in order to avoid the costs related to the errors [14–17].

The most important scope of the current study is to present a new model for forecasting of Turkey's PEC using regression analysis. The study is thought to be helpful for the energy planners and the policy makers in Turkey.

2. Literature review

2.1. Forecasting methods

Since the early 1970s, various studies focusing on the energy supply/demand have been carried out using various estimation methods, which can be broadly classified into five groups such as econometric and artificial intelligence approaches, hybrid, grey theory forecasting and long-range energy alternatives planning models [18].

2.1.1. Econometric approaches

Econometric approaches include linear regression (LR) and time series, etc. LR, whose core is least square method (LSM), is frequently used in the forecasting of future energy supply/demand, including general regression, partial least square regression (PLSR), log-linear regression and fuzzy regression (FR). Autoregressive integrated moving average (ARIMA) models are one of the most popular linear models for time series forecasting. ARIMA models have been originated from the autoregressive models (AR), the moving average models (MA) and the combination of the AR and MA, the ARMA models. ARIMA models can be used when the time series is stationary and there is no missing data within the time series. In ARIMA analysis, an identified underlying process is generated based on observations to a time series for generating a good model that shows the process-generating mechanism precisely [18–21].

2.1.2. Artificial intelligence approach

Artificial intelligence methods include artificial neural networks (ANNs), genetic algorithms (GAs), ant colony optimization (ACO) and particle swarm optimization (PSO) algorithm. ANNs are a class of flexible nonlinear models that can discover patterns adaptively from the data. It has been shown that given an appropriate number of nonlinear processing units, neural networks can learn from experience and can estimate any complex functional relationship. ANN has been successfully employed in energy forecasting. The greatest advantage of a neural network is its ability to model complex nonlinear relationship without a priori assumptions of the nature of the relationship like a black box [22]. GAs are optimizing and stochastic search techniques which possess vast and powerful applications. They consider a solution space and move intelligently towards the best solution while they are able to be trained by the data available and estimate for the kept part of the data called the trial period. The power of GA has recently been noticed due to its powerful search for identification of optimum parameters [23–25]. ACO belongs to the class of biologically inspired heuristics. The basic idea of ACO is to imitate the cooperative behavior of ant colonies. The principle of these methods is based on the way ants search for food and finds their way back to the nest. During trips of ants, a chemical trail called pheromone is left on the ground. The role of pheromone is to guide the other ants towards the target point. By one ant, the path is chosen according to the quantity of pheromone [26]. PSO is one of the recent meta-heuristic techniques based on natural flocking and swarming behavior of birds and insects. It is initialized with a population of random solutions and searches for optimal by updating generations. In PSO, the potential solutions called as particles, move through the problem space by following the current optimum particles. The individuals in a PSO have a position and a velocity. The PSO algorithm works by attracting the particles to search space positions of high fitness. Each particle has