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A hybrid algorithm of Ant Colony Optimization (ACO) and Iterated Local Search (ILS) for estimating electricity domestic consumption: Case of Turkey

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ABSTRACT

This paper presents the forecasting of Turkey's electricity domestic consumption using hybrid algorithm, which bases on Ant Colony Optimization (ACO) and Iterated Local Search (ILS) algorithms. The approximation forecasting of an important energy source like electric for countries such as Turkey, which greatly imported energy sources, is so vital. In this paper, electricity domestic consumption model is first proposed by hybrid approach of ACO and ILS. Both techniques are quite simple and powerful stochastic local search method. ACO uses pheromone update mechanism to escape the local optimum. ILS applies iteratively local search to an initial solution until finding a local optimum; then it perturbs the solution and restarts a local search. This paper aims combining the advantages of these two algorithms to perform successful estimations. We use some economic indicators such as population, gross domestic product (GDP), import and export when Hybrid Electricity Domestic Consumption Estimation (HEDCE) model is developed. HEDCE equations proposed here are linear and quadratic. Results show that Quadratic_HEDCE find better solution because it can reflect better the variations of used indicators. The HEDCE models forecast Turkey's electricity domestic consumption until 2030 under dissimilar scenarios.

Introduction

Energy for all country on the world is a vitally important position because it affects economy, social growth and life standards. Therefore, energy polices have to be analyzed and interpreted using the best approaches. Especially, decision makers in the developing countries like Turkey, consumption of the imported primary energy sources is forecasted correctly to use as an important policy tool. Turkey has geopolitically very important location, is a Eurasian country with its smaller part in Southeastern Europe and its larger part in Asia (i.e. the Balkans and Anatolia). Last decade, Turkey is one of the fastest growing energy markets in its area, which consist of Europe and Middle East because the mean of Turkey's economy growth between 2002 and 2013 years is about 5.1%. Fig. 1 shows the electricity domestic consumption for 2013 of all countries in the world [9]. Fig. 1 presents that electricity domestic consumption rate of Turkey is between 100 TW h and 200 TW h. Tukey's energy consumption increased to 198 TW h in 2013 from 103 TW h in 2002 [9].

The one of the biggest problem for Turkey's economy is current account deficit because Turkey's primary energy consumption is higher than its production. These energy sources are generally coal, oil, natural gas, solar energy, wood, both animal and plant wastes, geothermal and hydropower. Table 1 presents Turkey's energy production, consumption, electricity and carbon emission for last ten years.

Table 1 presents that using of Turkey's electricity consumption has been strongly increasing from 2004 to 2013 due to economic growth. The proportion of primary energy consumption covered by production was 25.8% in 2013 when it was 29.6% in 2004. The change of carbon emission between 2004 and 2013 is 33%.

Many researchers and scientists, who have been working on energy demand, study intensely about energy demand forecasting. In the energy literature, Turkey's energy demand was worked by State Planning Organization (SPO) [27], which is a public institution. This institution used the simple regression to forecast the Turkey's energy demand. However, some new approaches have been using to estimate Turkey's energy demand for 30 years. International Atomic Energy Agency (IAEA) proposed the model for analysis of energy demand to be used by Ministry of Energy and Natural Resources of Turkey [24]. The applying of the meta-

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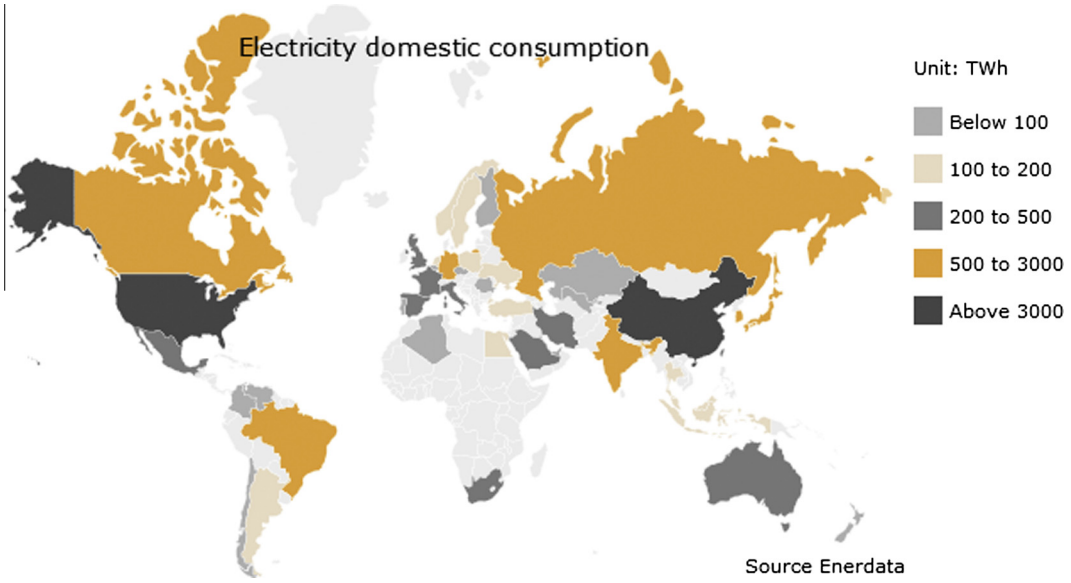

Fig. 1. The world's electricity domestic consumption (2013) [9].

Table 1
The values of Turkey's energy production, consumption, electricity and carbon emission [10].

Year	Primary energy (MTOE)		Electricity (TW h)	Carbon emission (Mt)
	Production	Consumption		
2004	24	81	121	203
2005	24	84	130	211
2006	26	93	143	235
2007	27	100	155	259
2008	29	99	162	258
2009	30	98	157	252
2010	32	105	172	262
2011	32	112	186	282
2012	32	115	195	285
2013	29	112	198	270
Change 2004–2013	21%	38%	64%	33%

heuristic approaches to forecast energy demand has been increasing in these days.

Table 2 summarizes the methods for forecasting of Turkey's electricity demand. However, any hybrid algorithm based ILS and ACO has never been proposed to estimate either the energy demand or the electricity consumption. The proposed algorithm should reach more accurate solutions within a shorter execution time if the proposed algorithm is compared to previous methods on Turkish electricity consumption forecasting. Since the proposed algorithm has superiority of both metaheuristic approaches (Ant Colony Optimization and Iterated Local Search). It can search wider area within the shorter time and escape the local optimal.

This paper presents two estimation models of Turkey's electricity domestic consumption using hybrid algorithm. We model these models using various forms (linear and quadratic) of equations and consider four economic indicators ((GDP), population and import and export) when performing model.

This paper introduces the hybrid application of ILS and ACO algorithms to estimate electricity domestic consumption. The proposed algorithm is a combined strategy based on the discrete (location optimization) and continuous (size optimization) structures to achieve advantages of the global and local search ability of algorithms.

The remainder of this paper is organized as follows: Sections 'Iterated Local Search (ILS) and Ant Colony Optimization (ACO)' will explain shortly ILS and ACO composing hybrid algorithm. Section 'Hybrid Electricity Domestic Consumption Estimation (HEDCE)' presents the proposed hybrid algorithm to forecast electricity domestic consumption. In Section 'Turkey's electricity domestic consumption models', Turkey's electricity domestic consumption models are proposed by using the hybrid algorithm. In next section, proposed models will estimate Turkey's electricity domestic consumption for 17 years under assumptions of two scenarios.

Iterated Local Search (ILS)

Iterated Local Search (ILS) is a simple and easy to implement when comparing with other meta-heuristic algorithms, but it is a successful and highly effective meta-heuristic. In summary, we modularize the ILS framework into three main components as described by Lourenco et al. [17]. The first component is local

Table 2
Turkish electricity consumption forecasting studies.

The used method	Forecasting for	Author(s)
Linear Regression (LR)	Electricity demand	Yumurtacı and Asmaz [29]
Seasonal Autoregressive Integrated Moving Average (SARIMA)	Electricity demand	Erdoğdu [11]
Grey Prediction with Rolling Mechanism (GPRM)	Electricity demand	Akay and Atak [1]
Artificial Neural Network (ANN)	Electricity consumption	Hamzaçebi [12]
	Electricity consumption	Kavaklıoğlu et al. [15]
Ant Colony Optimization (ACO)	Electricity demand	Toksari [25]