DEMAND ANALYSIS AND FORECASTING FOR ELECTRICITY IN TURKEY FOR THE YEARS 2000-2020

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Abstract

We conducted a study, which aims to analyze the demand for electricity and forecast the consumption of Turkey in a 20 years time period. We assumed demand for electricity as a function of population, economic factors and net income; and environmental and psychological factors. We used the following tools and techniques in the study: pattern analysis, trend models, quadratic models, adaptive smoothing models, seasonal models, growth models, exponential models, test of hypothesis, validity, and accuracy. The research attempted to define and analyze electricity consumption as an equation in conjunction with: gross national product (GNP), gross domestic product (GDP), population growth, as well as the GDP-portions of various sectors such as: heavy industry, manufacturing, construction and trade. In the analysis we were concerned with the problem of finding the "best-fitting" curve or line describing the relation between Electricity Consumption, a random variable over time horizon of 23 years and experimental effecting variables, GNP, GDP etc. In conclusion, we can say that, in addition to regression model, S-Curve Trend Model is the best fit to the obtained data. Demand for electricity for the year 2020 is estimated as 436638 GW/h. For the same year quadratic estimation is 327965 GW/h. Finally, our results are compared with alternative forecasts such as TEAŞ, Cambridge Energy Research Associates (CERA) and Energy Information Administration (EIA).

***Key Words*:** *Forecasting, Demand, Electricity, and Turkey*

1. Introduction

Forecasting demand for customer service begins with having the right product or service, in the right quantity, at he right time, in the right location. This forecasting is only achievable through excellence in operational forecasting systems but not forecasting methods. A forecasting method is a mathematical or subjective technique that predicts some future value or event. Many available statistical forecasting software packages are implementations of forecasting methods, they are not forecasting systems. A forecasting system is a computer-based system that collects and process demand data for thousands of items, makes forecasts using methods, has an interactive management-user interface, maintains a database of demands, detects out-of-control situations, and has report- and file-writing capabilities. Thus, this study, briefly deals with forecasting systems including forecasting methods in it. Throughout the study, statistical analyses were performed by using Minitab Release 13.20.

2. Electricity Demand Forecast

2.1. Variables used in Demand Analysis

In order to develop a realistic generation plan for Turkey, one of the more challenging tasks is to derive a demand forecast for the complete Turkish power system. For this purpose, an extensive analysis with various tools and techniques was performed to develop such a forecast. The results of three modeling methods, which seem to reflect possible demand growths in the future, have been chosen for our high, medium and, low forecast scenarios.

Demand for electricity may be determined as:

$$D_{et} = f (P_t , I_t , S_t , E_t)$$

Where: D_{et} is defined as demand for electricity at time t,

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P_t is defined as population at time t,
I_t is defined as economic factors, net income at time t,
S_t is defined as savings at time t,
E_t is defined as environmental and psychological factor at time t.

Within the context of this study, we attempted to define and analyze electricity consumption as an equation in conjunction with: gross national product (GNP), gross domestic product (GDP), population growth, as well as the GDP-portions of various sectors such as: heavy industry, manufacturing, construction and trade.

Figure-1 highlights the annual gross generation (gross domestic generation, plus imports, minus exports) over the last twenty years. The curves exemplify that during the last 10 years, average growth rates of about 8 to 9 % have been achieved. It explains annual net (billed) consumption, as well as average losses, which are given as a percentage of gross generation. The graph shows that losses have steadily increased over the last two decades to a level of 22 % of the gross generation in 1999. The losses can be separated into power station auxiliary consumption, transmission losses and distribution losses.

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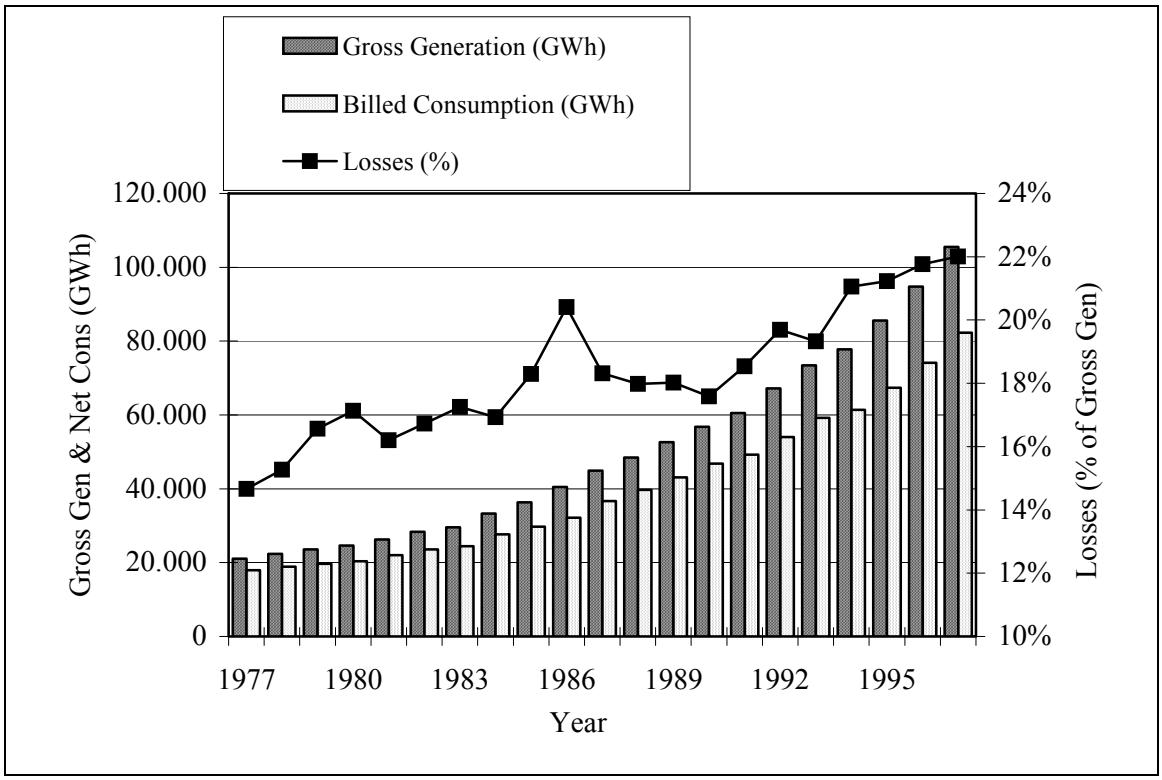

Figure 1.Historical gross generation and net consumption

The level of non-technical losses in Turkey including domestic and non-domestic, are exceptionally high when compared to the losses in other European countries. This is especially true for the South-East Anatolian provinces. In order to decide whether to include non-technical losses in demand growth analysis, the following key points are decisive in this decision making process:

- Due to the low per capita consumption (1,725 kWh per capita compared with Greece's 4,500 kWh per capita for year 2000), domestic non-technical losses seem essential for daily usage and it appears that these will be almost completely shown as ''billed'' after privatization of the distribution system.
- Over 50 % of electricity consumption is from industry. When the electricity sector is privatized, all consumed energy by the industry will be ''billed''.

Consumption of electricity by the year 2004 shall increase by homeowners due to increase in sales of air conditioners, electric ovens, water pumps etc. in apartment buildings and private homes.

Electrical operated loan-movers, Internet, computers, electrical telephones, etc. will increase the consumption of electricity ever before on the average 5 to 7% more than before under similar conditions. This additional increase in electricity consumption may not be explained in the statistical analysis as causal effect. Greece's electricity consumption of 4500 kwh per capita then may be caught at the year of 2035. Annual population growth of 1.5% is included in the aggregate demand prediction for electricity consumption.

Examining the underlying trend for electricity consumption in the years 1977-1999; clearly indicates that there exists a long-term pattern of growth.

Comparing the annual growth values indicate that GDP growth has been erratic from year to year, from a high of 10 % in 1987 to a low of minus 6 % in 1994. The breakdown of GDP by sector indicates that the main change in terms of contribution has been an increase in share from the industrial sector at the expense of the agricultural sector.

The general growth pattern in population indicates a declining growth rate of about 1.5 % per annum. The decline in population growth is mainly due to the fall in the fertility. Fertility is estimated to have fallen to about 2.0 children per woman. In the more rural provinces to the East, fertility rates remain comparatively higher than that of Western Turkey, although in real terms are declining rapidly. In the long-term it can be expected that population growth be expected to will fall to 1.0 child per woman, and ultimately population growth will decrease. This general trend is consistent with that of other developing, as well as, developed countries.

The fall in fertility reflects the continued urbanization of Turkey since younger families in the urban areas generally choose lifestyles, which include a reduction in the number of offspring. In Turkey there is a growing proportion of population in urban areas. The migration of people from Eastern Anatolia has been the main driving factor for the growth of population western cities such as Istanbul, Bursa, Ankara and Izmir. It is also in these cities where fertility rates are below the national average.

The data for electrification indicate that, since 1988 over 99 % of villages have been electrified. In 1996, the percentage was 99.97 %. We can conclude that an insignificant amount of electricity growth can be associated with rural electrification in the last decade and that the whole country can now be considered as electrified with no further growth potential from rural electrification.

2.2. Methods Used for the Demand Forecast

The tools and techniques utilized for forecasting the demand growth for this study were: Pattern analysis, Trend models, Adaptive smoothing models, Seasonal models, Growth models, and Exponential models.

Although it has been possible to define electricity consumption with various regression equations using a vast variety of driving variables, three modeling methods which show the consumption as an equation of time, seem to express the best possible demand growth scenarios in Turkey for a 20 year time horizon:

- S - Curve Trend Model: $GWh\ (t) = 10^3 / (0{,}949952 + 58{,}6932 \times 0{,}913943^{\,t-1})$
- Quadratic Trend Model: $GWh\ (t) = 18{,}7672 - 0{,}239391 \times t + 0{,}165480 \times t^2$
- Double Exponential Smoothing

Figures 2,3 and 4, show that the actual values of electricity consumption coincide with that of the curves created through the utilization of the aforementioned models, and that the extension of the curves are indicative of future consumption rates:

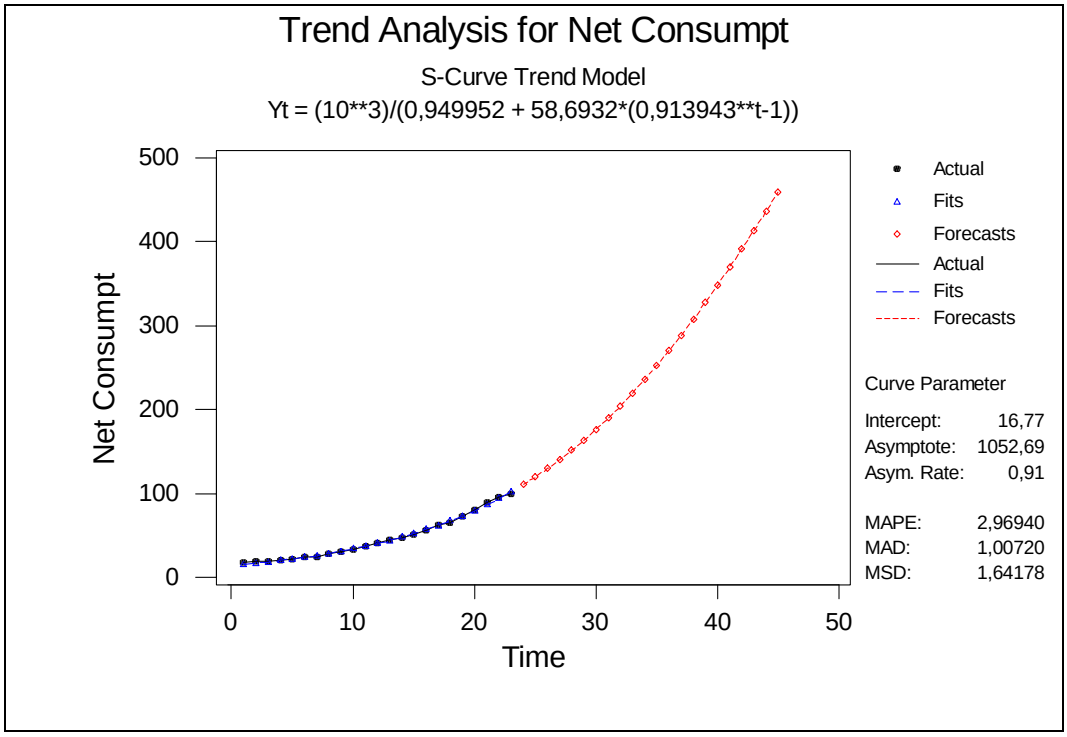

Figure 2. S-Curve trend model for net consumption

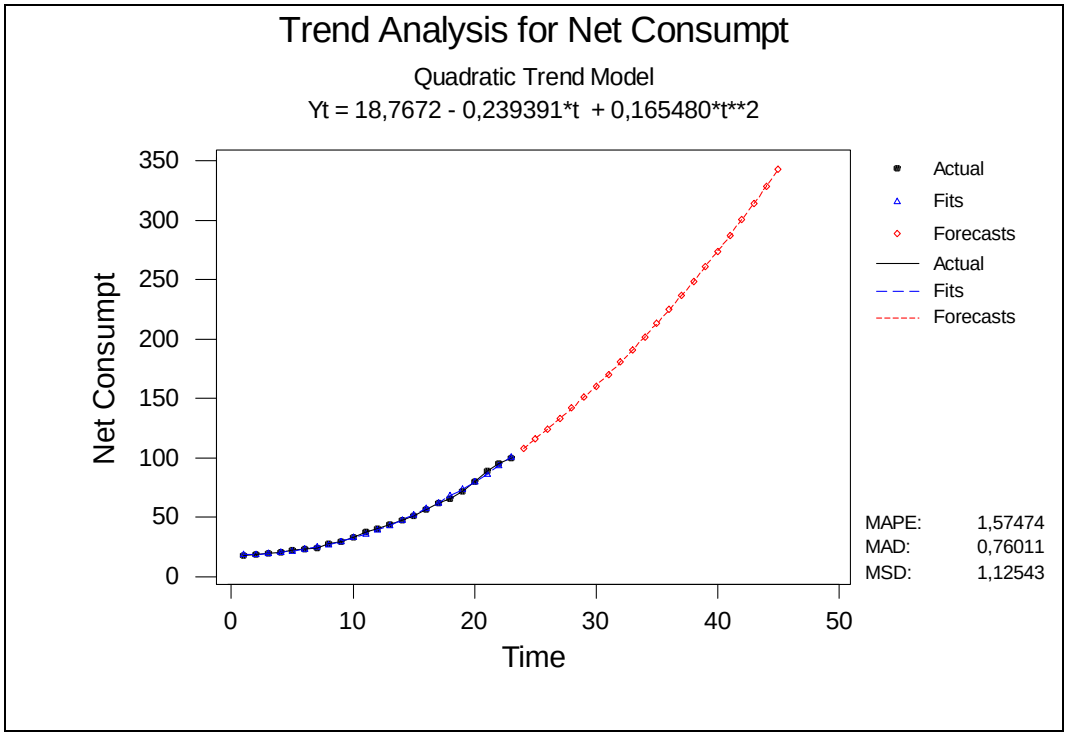

Figure 3. Quadratic trend model for net consumption

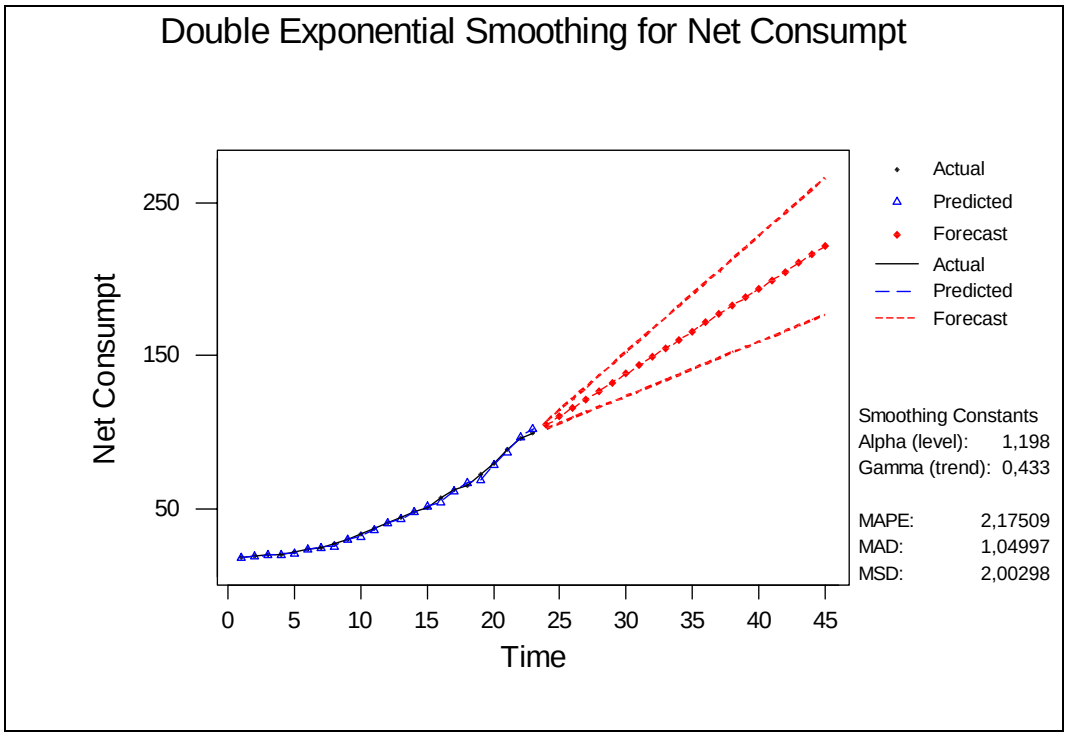

Figure 4.Double exponential smoothing trend model for net consumption

Table 1.Demand forecast modeling for net consumption

Modelling Method	Net Consumption incl. Non-technical Losses (GWh) Year 2010	Net Consumption incl. Non-technical Losses (GWh) Year 2020
S-curve Trend Model	235,512	436,638
Quadratic Trend Model	201,922	328,603
Double Exponential Smoothing	160,467	216,054

The aforementioned results were derived from historical data pertaining to a 22-year period (1977-1999).

When adding the technical distribution losses with an average of 7%, and the transmission losses with an average of 3%, to the net consumption, the following net generation (at transmission) and average growth results for year 2010 and 2020 are obtained:

Table 2. Forecast for net generation (at transmission)

Modelling Method	Net Generation (GWh) Year 2000 (est.)	Net Generation (GWh) Year 2010	Net Generation (GWh) Year 2020
S-curve Trend Model	122,438	235,114	435,926
Quadratic Trend Model	120,004	201,662	330,241
Double Exponential Smoothing	116,244	164,744	221,504

Table 3. Average growth in net generation

Modelling Method	Average Growth 2000 – 2010	Average Growth 2010 – 2020
S-curve Trend Model	6.7 %	6.4 %
Quadratic Trend Model	5.5 %	5.0 %
Double Exponential Smoothing	3.5 %	3.0 %

3. Alternative Forecasts

In January 2001, TEAŞ had published a generation plan designed for internal distribution. The Table 4. summarises the gross generation and maximum demand forecasts for selected years from this plan.

Table 4. TEAŞ forecast for gross generation

Year	Gross Generation (GWh)	Demand Growth (%)	Maximum Demand (MW)
2001	139,750	8.9	22,307
2005	195,463	8.8	31,011
2010	286,586	8.0	45,387
2015	402,932	7.1	63,341
2020	566,512	7.1	88,397
2025	758,880	6.0	117,733
2030	990,321	5.5	152,720

The Demand Forecast stated in the *VIII. Five Year Development Plan* published by SPO (State Planning Organisation) in year 2001 indicates very similar figures:

294,530 GWh for year 2010 and 555,690 GWh for year 2020, respectively.

The forecast was developed by the Ministry of Energy & Natural Resources (MENR) utilising the MAED model (Model for Analyses of Energy Demand). The key assumptions utilised in the MAED model to arrive at the load forecast are as follows:

- A decrease in population growth from 1.5 % to 1.0 %
- GDP growth rate of 4.7 / 5.0 / 5.7 % in year 2005 / 2010 / 2020, respectively.
- Employment of 81 / 97 % in year 2010 / 2020, respectively.

By 2010 and 2020, per capita consumption is estimated to be 3,974 kWh and 6,794 kWh respectively. Comparing these figures with the present values for Greece which an average of 4,700 kWh, and over 6,000 kWh on average for European OECD countries indicates that as Turkey continues to develop, the consumption trend towards that of developed countries coincides.

The Cambridge Energy Research Associates (CERA) has provided a high and low forecast for growth in electricity demand of 6.2 % and 4.9 % respectively over the period 1997 to 2010. The latter assumes a growth in GDP of 3.5 %, while the former assumes a growth in GDP of 5 %. This figure is based on the assumption that inflation is brought under control to enable faster economic expansion.

In December 2000, the Energy Information Administration (EIA), an administration established by the US Department of Energy, has published the International Energy Outlook 2001, which includes a World Net Electricity Consumption Forecast by Region. The forecast including Turkey indicates the following projections in Table 5.:

Table 5. EIA forecast for net consumption (TWh)

	Year 2005	Year 2010	Year 2015	Year 2020	Average Growth 1999 – 2020
Reference Case	127	150	176	205	3.2 %
High Growth Case	133	166	203	248	4.2 %

Figure 5. shows the consumption per capita (on the Y1 axis) and consumption per US$ 1.000 of GDP (on the Y2 axis) over a 20-year period.

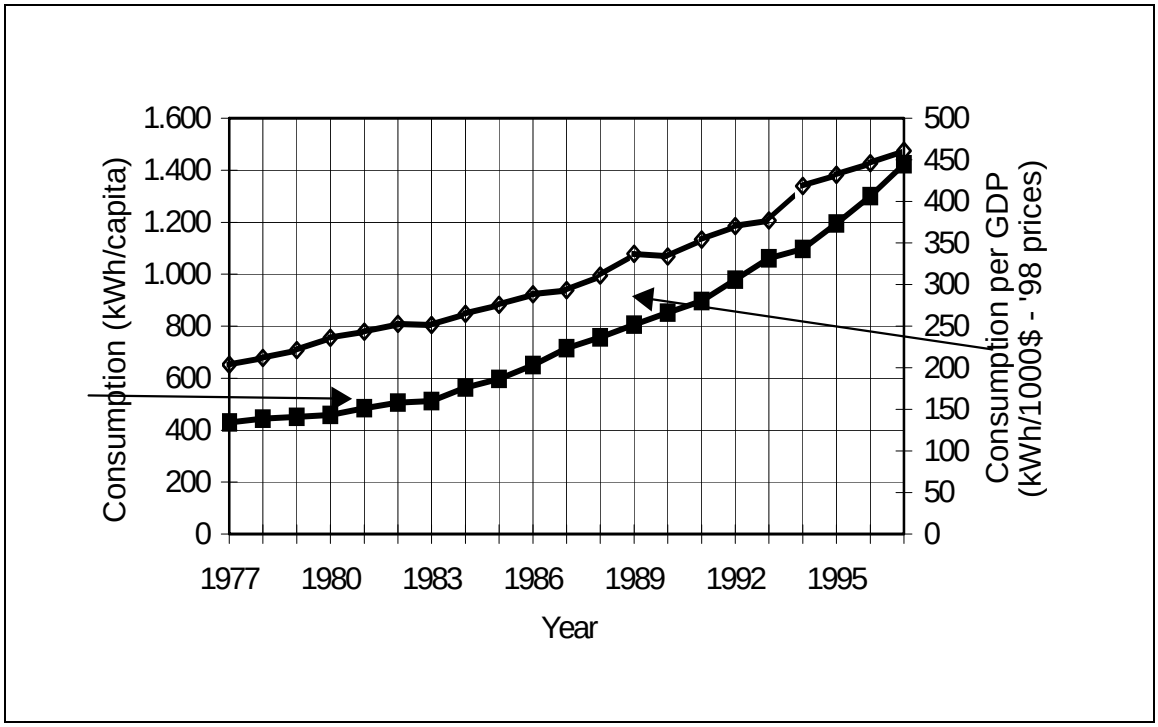

Figure 5. Ratios of electricity consumption to population and gross domestic product

In 1999, per capita consumption was estimated to be 1,642 kWh. By comparison, the average per capita consumption for European OECD countries is over 6,000 kWh. Greece, a better comparator due to similar climate and geography, has an average per capita consumption of 4,073 kWh. At the present rate of growth per capita consumption in Turkey, this level could only be possibly reached by 2012.

In 1999, consumption per US$ 1.000 of GDP in 1990 constant prices was about 550 kWh. By comparison, the average for Italy and Spain are about 220 and 320 kWh. In part, Turkey's relatively high consumption, compared to the GDP, reflects the lesser developed economy of Turkey, though at the same time we have already noted that a significant proportion of Turkey's economy remains undeclared. It has also been suggested that the Turkish industrial sector is more electricity consumption intensive, although this may also reflect inefficient uses of energy.

We can also look to 'peer' countries, such as Spain, Italy, Portugal and Greece, who have similar climates and geographies, but who are further economically developed. Indicators such as GDP and

electricity consumption for these countries may provide a useful goal or top limit for forecasting demand in Turkey. The statistics presented in Table 6. are for the years 1990 to 1999.

Table 6. Peer country statistics 1990-1999

Country	1999 GDP/capita in 1990 prices (USD)	Average Growth in GDP/capita 1990-1999	KWh / capita 1999	Average Growth in kWh/capita 1990-1999	Elasticity ('multiplier')
Turkey	$3 087	1.6%	1 642	7.0%	2.73
Greece	$9 389	1.6%	4 073	3.2%	1.78
Portugal	$8 547	2.3%	3 798	4.2%	1.81
Spain	$15 239	2.1%	4 812	3.8%	1.76
Italy	$21 645	1.2%	4 737	2.1%	1.68
Thailand	$2 030	3.2%	1 359	7.0%	1.90
Mexico	$3 557	1.2%	1 757	3,4%	1.72

For European countries, we noted that the countries are significantly more advanced in terms of per capita GDP, with values ranging between 2.8 and 7.0 times as great as Turkey. While per capita consumption varied between 2.3 to 3.0 times as great. The average per capita consumption and GDP for the four European peer countries is about 4000 kWh and US$ 10.000 respectively, compared with Turkey's 1,642 kWh and US$ 3087. Elasticity of less than unity would be required to enable the per capita GDP to surpass the rate of consumption.

In summary, we have used the results of the chosen modelling methods for our three demand forecast scenarios as shown in Table 7.:

Table 7. Demand forecast scenarious

Modelling Method	Demand Forecast Scenario	Average Growth 2000 – 2010	Average Growth 2010 – 2020
S-curve Trend Model	High	6.7 %	6.4 %
Quadratic Trend Model	Medium	5.5 %	5.0 %
Double Exponential Smoothing	Low	3.5 %	3.0 %

Table 8. Summary of alternative forecast and historical growth to 2010

Source	GDP Growth	Growth in terms of Electricity Demand	Elasticity of Electricity Demand to GDP
TEAŞ / MENR	5%	8.0%	1.6
CERA	3.5% & 5.0%	4.9% & 6.2%	1.4 to 1.2
EIA	N/A	3.2% & 4.2%	N/A
Historical Average (1979- 1999)	4.0%	8.5%	2.1

When we compare our demand growth forecast in Table 7. with the alternative forecasts in Table 8. , the following can be inferred:

- During the recession experienced in 1994, demand growth was about 6 %, which makes us optimistic about the rapid recovery of the Turkish economy with a high demand growth of 6.7 % and 6.1 % in year 2010 and 2020.
- Our medium demand forecast is near to that of CERA's high demand forecast. With a rapid recovery, but with a slightly negated effect resulting from privatisation, we think that Turkey can experience demand growth of 5.5 % and 5.0 % in year 2010 and 2020.
- Our low demand forecast is as pessimistic as the EIA's, considering that the possibility of a world-wide economical recession will continue in the future, which will cause the Turkish economy not to recover as quickly as estimated.

Future patterns of electricity demand, expressed as load duration curves, are required in the generation planning process so that the dispatch of system generation may be simulated.
There are currently about 1000 substations in Turkey at the 380 kV and 154 kV level mostly located in Istanbul, Ankara, Izmir and the neighbouring areas, where 60 % of the total electrical energy is consumed. When we examine the load patterns of these provinces, we see that summer and winter load patterns are close to each other.
In recent years, a significant demand growth is being observed in Gaziantep and Diyarbakır on south east of Anatolia, and in Adana, Kahramanmaraş and Osmaniye due to increased industrialization, as well as on the Mediterranean Coast, due to the increasing tourism. It can be expected in the following years that the peak load in winter times (mostly in December) will be shifted to summer times.

4. Conclusions

In the analysis we were concerned with the problem of finding a "best-fitting" curve or line describing the relationship between Electricity Consumption, a random variable over time horizon of 23 years and experimental effecting variables, GNP, GDP etc. In conclusion, we can say that, S-curve Trend Model known as Pearly-Reed Logistics Function, is the best fit to the obtained data. Demand for electricity for the year 2020 is estimated as 436638 GWh. For the same year quadratic estimation is 327965 GWh. Using our hunches and guesses 2020 electricty consumption for Turkey will be 350000GWh with a standard deviation 10000 GWh.

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