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Estimation of Turkey Electric Energy Demand until Year 2035 Using TLBO Algorithm

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Abstract: In this study, the estimation of Turkey primary electric energy demand until 2035 is tried to estimate by using Teaching-Learning Based Optimization (TLBO) Algorithm. Two models are proposed which are based on economic indicators TLBO algorithm linear energy demand (TLBOEDL) and TLBO algorithm quadratic energy demand (TLBOEDQ). In both of these two models the indicators used are Gross Domestic Product (GDP), population, importation and exportation. After a comparison of these two models with real values between 1979 and 2005 years, it is applied to the estimation of Turkey electric energy demand until 2035 by three different scenario. The estimation results are suitable with the estimation of Turkey total primary energy supply of 2013 Energy Report of World Energy Council Turkish National Committee (WEC-TNC).

Keywords: *Teaching Learning Based Optimization (TLBO) Algorithm, Energy Demand Estimation, TLBOEDL Model, TLBOEDQ Model, Turkey Energy Report 2013.*

1. Introduction

Energy is the most important need of developed and developing countries. Energy is an indispensable fact which its importance has been growing gradually. It is the most important means in the development of countries. Energy consumption has been increased with the growth in world population. The economic growth leads to energy consumption and energy consumption leads to economic growth [1]. Therefore the energy demand has been increasing despite important nuclear power plant accidents and financial crisis. Foreign energy dependency of Turkey as % 70 percentage obliges the special policies and special behavior styles as society on energy subject [2].

To meet the electrical energy of society economically, supply, demand, transmission, contribution and pricing policies should be constituted effectively. Moreover, ease of use of electrical energy for consumers, non-storability of electrical energy increases the importance of demand studies on electrical energy area [3]. Energy demand estimation has a critical role in energy agreements between countries. The excessive deviation leads to the economical deficits.

Although demand studies on energy have been studies in Western countries for a long time, the studies have accelerated at the end of 1990s in our country. State Planning Organization, State Statistical Institute and Ministry of Energy and Natural Sources have been used the mathematical models for the energy demand at the last of 1970s [4].

Recently, many studies on the Turkey primary energy demand have been done. In these studies, different methods, different scenarios with various data and variables for many terms have been used [3]. Some studies on this research area are the energy demand by Genetic Algorithm [3-7], energy consumption estimation by Artificial Neural Networks (ANN) [8-10], energy demand by Ant Colony Optimization (ACO) [11] and energy demand estimation by hybrid Algorithm [12].

Generally, any event which is wanted to model in terms of estimation by mathematically, as the numbers of variables are getting increased, correct estimation possibility decreases [3]. In this study, the estimation of Turkey energy demand until 2035 is try to estimate by using some economical variable indicators such as Gross Domestic Product (GDP), population, importation and exportation.

2. Teaching Learning Based Optimization (TLBO) algorithm

TLBO algorithm is a social based optimization algorithm which depends on interaction between students and teachers in a class. At every step of algorithm, successful students are elected and the best students have been determined [13].

It has three parameters which is the number of students, number of classes and iteration number. TLBO algorithm has two phases which are teacher and student phases.

At teacher phase of the algorithm, students learn from the teacher by imitating. Teacher is the most experienced and the most informed person so the best student can learn as much as the teacher.

Between teacher and student's learning capacity, there is an average difference called difference mean and it is defined as Eq. 1,

$$\text{Difference\_Mean}_{j,i} = r_i \left(X_{j,kbest,i} - T_f M_{j,i} \right) \quad (1)$$

where r_i is a random number between 0 and 1, $X_{j,kbest,i}$ is the

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result of teacher (the best result) and T_f is teaching factor between 1 and 2.

T_f is defined as Eq. 2,

$$T_f = \text{round}\left[1+\text{rand}(0,1)\ \{1,2\}\right] \quad (2)$$

If difference mean is better than present result, Eq. 2 is arranged as Eq. 4, the best function result is given by Eq. 3,

$$X'_{j,k,i} = X_{j,k,i} + \text{Difference\_Mean}_{j,k,i} \quad (3)$$

Where $X'_{j,k,i}$ is the best function result accepted.

After teacher's phase, all best function values are kept to use at student's phase. At this stage, students learn the knowledge by interacting and by discussing between them. If a student is more knowledgeable, the other is updating himself by interaction.

P and Q are the random students are given in Eq. 4,

$$X'_{total-P,i} \neq X'_{total-Q,i} \quad (4)$$

Where $X'_{total-P,i}$ and $X'_{total-Q,i}$ are updated values of $X_{total-P,i}$ and $X_{total-Q,i}$

If $X'_{total-P,i} > X'_{total-Q,i}$ $X''_{j,P,i}$ is obtained as Eq. 5

$$X''_{j,P,i} = X'_{j,P,i} + r_i(X'_{j,P,i} - X'_{j,Q,i}) \quad (5)$$

and if $X'_{total-Q,i} > X'_{total-P,i}$ $X''_{j,P,i}$ is obtained as Eq. 6

$$X''_{j,P,i} = X'_{j,P,i} + r_i(X'_{j,Q,i} - X'_{j,P,i}) \quad (6)$$

$X''_{j,P,i}$ is accepted as the best function value [13].

3. Estimation of Turkey Energy Demand With TLBO (TLBOED)

Economical variable indicators such as Gross Domestic Product (GDP), population, importation and exportation for energy demand estimation is try to estimate by using TLBO algorithm. TLBOEDL and TLBOEDQ models are proposed depending on economic indicators. It is seen from the literature that Linear and quadratic models have been studied commonly [11, 12, 14-16]. Economic indicators of Turkey between 1979 and 2005 are given in Table 1 [17, 18].

The linear model proposed by TLBO algorithm as in Eq. 7,

$$E_{TLBOEDL} = w_1.X_1 + w_2.X_2 + w_3.X_3 + w_4.X_4 + w_5 \quad (7)$$

Quadratic model equation is given in Eq. 8,

$$\begin{aligned} E_{TLBOEDQ} = {} & w_1.X_1 + w_2.X_2 + w_3.X_3 + w_4.X_4 \\ & + w_5.X_1.X_2 + w_6.X_1.X_3 + w_7.X_1 \\ & .X_4 + w_8.X_2.X_3 + w_9.X_2.X_4 \\ & + w_{10}.X_3.X_4 + w_{11}.X_1^2 + w_{12}.X_2^2 \\ & + w_{13}.X_3^2 + w_{14}.X_4^2 + w_{15} \end{aligned} \quad (8)$$

w_i and X_i coefficients are used in two proposed models. w_i coefficients are defined as design parameters. There isn't any limitation for design parameters ($-\infty < w_i < +\infty$).

X_1, X_2, X_3, X_4 are constants and these are defined as Gross Domestic Product (GDP), population, import and export respectively. The objective function in energy demand estimating is given by Eq. 9,

$$\min f(v) = \sum_{r=1}^{m} (E_r^{observed} - E_r^{predicted})^2 \quad (9)$$

Where $E^{observed}$ and $E^{predicted}$ are the actual and predicted energy demand, respectively, m is the number of observations.

Table 1. Energy demand, GDP, population, import and export data of Turkey [17,18].

Year	Energy Demand (MTOE)	GDP ($\$10^9$)	Population (10^6)	Import ($\$10^9$)	Export ($\$10^9$)
1979	30,71	82,00	43,53	5,07	2,26
1980	31,97	68,00	44,44	7,91	2,91
1981	32,05	72,00	45,54	8,93	4,70
1982	34,39	64,00	46,69	8,84	5,75
1983	35,70	60,00	47,86	9,24	5,73
1984	37,43	59,00	49,07	10,76	7,13
1985	39,40	67,00	50,31	11,34	7,95
1986	42,47	75,00	51,43	11,10	7,46
1987	46,88	86,00	52,56	14,16	10,19
1988	47,91	90,00	53,72	14,34	11,66
1989	50,71	108,00	54,89	15,79	11,62
1990	52,98	151,00	56,10	22,30	12,96
1991	54,27	150,00	57,19	21,05	13,59
1992	56,68	158,00	58,25	22,87	14,72
1993	60,26	179,00	59,32	29,43	15,35
1994	59,12	132,00	60,42	23,27	18,11
1995	63,68	170,00	61,53	35,71	21,64
1996	69,86	184,00	62,67	43,63	23,22
1997	73,78	192,00	63,82	48,56	26,26
1998	74,71	207,00	65,00	45,92	26,97
1999	76,77	187,00	66,43	40,67	26,59
2000	80,50	200,00	67,42	54,50	27,78
2001	75,40	146,00	68,37	41,40	31,33
2002	78,33	181,00	69,30	51,55	36,06
2003	83,84	239,00	70,23	69,34	47,25
2004	87,82	299,00	71,15	97,54	63,17
2005	91,58	361,00	72,97	116,77	73,48

We give the algorithm of our TLBOED method below:

Step 1: Define the optimization problem and initialize the optimization parameters.

Initialize the population size (P_n), number of generations (G_n), number of design variables (D_n), and limits of design variables (U_L, L_L).

Define the optimization problem as Eq. 10:

$$\min f(v) = \sum_{r=1}^{m} (E_r^{observed} - E_r^{predicted})^2 \quad (10)$$

Subject to $w_i \in w_i = 1,2,\ldots,D_n$

where $f(v)$ is the objective function, w is a vector for design variables such that $-\infty < w_i < +\infty$.

Step 2: Initialize the population.

Generate a random population according to the population size and number of design as Eq. 11 variables.

$$\text{population} = \begin{bmatrix} w_{1,1} & w_{1,2} & \cdots & w_{1,D} \\ w_{2,1} & w_{2,2} & \cdots & w_{2,D} \\ . & . & . & \\ . & . & . & \\ . & . & . & \\ w_{P_n,1} & w_{P_n,2} & \cdots & w_{P_n,D} \end{bmatrix} \quad (11)$$

Step 3: Teacher phase.
Calculate the mean of the population column-wise, which will give the mean for the particular subject as Eq. 12,

$$M,_D = [m_1, m_2, ..., m_D] \quad (12)$$

The best solution will act as a teacher for that iteration in Eq. 13,

$$W_{teacher} = W_{f(W)=min} \quad (13)$$

The teacher will try to shift the mean from $M,_D$ towards $W,_{teacher}$ which will act as a new mean for the iteration. So,

$$M\_new,_D = W_{teacher,D} \quad (14)$$

The difference between two means is expressed as Eq. 15,

$$Difference,_D = r\,(M\_new,_D - T_F M,_D) \quad (15)$$

The value of T_F is selected as 1 or 2. The obtained difference is added to the current solution to update its values using Eq. 16.

$$W_{new,D} = W_{old,D} + Difference,_D \quad (16)$$

Accept W_{new} if it gives better function value.
Step 4: Learner phase.
Learner modification is expressed as

For $i = 1 : P_n$
Randomly select two learners W_i and W_j, where $i \neq j$
If $f(W_i) < f(W_j)$
$W_{new,i} = W_{old,i} + r_i(W_i - W_j)$
Else
$W_{new,i} = W_{old,i} + r_i(W_j - W_i)$
End If
End For

Accept W_{new} if it gives a better function value.
Step 5: Termination criterion. Stop if the maximum generation number is achieved; otherwise repeat from Step 3.

4. Experimental Studies

TLBOED algorithm is proposed for Turkey energy demand estimation between 1979 and 2005 years by using economic indicators taken from MENR. Minimum objective function is obtained by calculating for TLBOEDL model. In Eq. 17, population size (P_n) is taken as 25, number of design variables (D_n) are taken as 5 and the number of generations (G_n) is taken as 1000 and $f(v)_{TLBOEDL}$ is obtained as 41,712.

$$E_{TLBOEDL} = 0{,}003805955X_1 + 1{,}9122747919X_2 + 0{,}3735435225X_3 - 0{,}4835157988X_4 - 55{,}899091016 \quad (17)$$

Minimum objective function is obtained by calculating for TLBOEDQ model. In Eq. 18, population size (P_n) is taken as 25, number of design variables (D_n) are taken as 15 and the number of generations (G_n) is taken as 10.000. Minimum $f(v)_{TLBOEDQ}$ is obtained as 19,32921.

$$\begin{aligned} E_{TLBOEDQ} = & -0{,}01833664807X_1 + 0{,}1271526286X_2 \\ & -0{,}7303814145X_3 + 1{,}5173167741X_4 \\ & +0{,}0057624768X_1X_2 + 0{,}0118978356X_1X_3 \\ & -0{,}0079494952X_1X_4 - 0{,}0013078678X_2X_3 \\ & -0{,}0149756126X_2X_4 + 0{,}0365796927X_3X_4 \\ & -0{,}0017245010X_1^2 + 0{,}0096564193X_2^2 \\ & -0{,}0234475391X_3^2 - 0{,}0197717121X_4^2 \\ & -2{,}0471885591 \end{aligned} \quad (18)$$

TLBOEDL and TLBOEDQ estimation models were executed for 50 times and best results were considered by given parameters in Eq. 17 and Eq. 18.
TLBOEDL and TLBOEDQ models which are formed by taking the data from Table 2 are effective and successful according to data between 1996 and 2005 years.
In Table 2, the biggest decrease in energy demand is in 2001. In Table 1, a considerable decrease is seen for the same year 2001. This situation results from the economic crisis in 2001.

Table 2. Energy demand estimation of TLBOED models between 1996 and 2005 years.

Years	Observed energy demand (MTOE)	Estimated energy demand (MTOE)		Relative errors (%)	
		Linear	Quadratic	Linear	Quadratic
1996	69,86	69,71	69,85	-0,21	-0,02
1997	73,78	72,32	72,71	-1,99	-1,45
1998	74,71	73,30	74,28	-1,89	-0,58
1999	76,77	74,18	75,27	-3,37	-1,95
2000	80,50	80,71	80,96	0,27	0,57
2001	75,40	75,71	74,79	0,42	-0,81
2002	78,33	79,13	79,68	1,02	1,72
2003	83,84	82,36	83,70	-1,76	-0,16
2004	87,82	87,19	87,30	-0,72	-0,60
2005	91,58	93,10	91,92	1,66	0,37

Three different scenario have been constituted for Turkey 2013-2035 energy demand estimation. Scenarios are made by utilizing the data from Turkish Standards Institute [17]. Scenarios are compared to 2006-2012 demand [18] and our estimation models in Table 3, Table 4, and Table 5. At later stage, estimations until 2035 is obtained.

Table 3. Energy demand estimation of TLBOED between 2006 and 2012 years according to scenario 1.

Years	Observed energy demand (MTOE)	Estimated energy demand (MTOE)		Relative errors (%)	
		TLBOEDL	TLBOEDQ	TLBOEDL	TLBOEDQ
2006	99,59	95,96	95,19	-3,78	-4,62
2007	107,63	98,90	98,62	-8,83	-9,14
2008	106,34	101,94	102,21	-4,32	-4,04
2009	106,14	105,09	105,97	-1	-0,16
2010	109	108,34	109,91	-0,61	0,83
2011	115	111,71	114,01	-2,95	-0,87
2012	121	115,19	118,30	-5,04	-2,28

Table 4. Energy demand estimation of TLBOED between 2006 and 2012 years according to scenario 2.

Years	Observed energy demand (MTOE)	Estimated energy demand (MTOE)		Relative errors (%)	
		TLBOEDL	TLBOEDQ	TLBOEDL	TLBOEDQ
2006	99,59	96,14	95,32	-3,59	-4,48
2007	107,63	99,29	98,91	-8,4	-8,82
2008	106,34	102,55	102,7	-3,7	-3,54
2009	106,14	105,93	106,68	-0,2	0,51
2010	109	109,44	110,86	0,4	1,68
2011	115	113,08	115,26	-1,7	0,23
2012	121	116,87	119,86	-3,53	-0,95

Table 5. Energy demand estimation of TLBOED between 2006 and 2012 years according to scenario 3.

Years	Observed energy demand (MTOE)	Estimated energy demand (MTOE)		Relative errors (%)	
		TLBOEDL	TLBOEDQ	TLBOEDL	TLBOEDQ
2006	99,59	95,45	94,53	-4,34	-5,35
2007	107,63	97,86	97,26	-9,98	-10,66
2008	106,34	100,35	100,09	-5,97	-6,24
2009	106,14	102,91	103,05	-3,14	-3
2010	109	105,55	106,12	-3,27	-2,71
2011	115	108,27	109,31	-6,22	-5,21
2012	121	111,07	112,63	-8,94	-7,43

From the Tables (3-5), the estimations by TLBOED model is close to the observed demand values. According to these tables, decrease in the demand in 2008-2009 years shows that the crisis worldwide was affected the Turkey as little.

Scenarios are compared to Turkey primary energy supply and demand estimations according to World Enegy Council Turkey National Committee.

Scenario 1: It is assumed that the average growth rate of GDP is 4.7%, population growth rate is 0.11%, import growth rate is 4.5%, and export growth rate is 2% during the period of 2013-2035. The obtained results are compared to WEC-TNC Turkey 2013 Energy Report in Table 6 and Figure 1.

Scenario 2: It is assumed that the average growth rate of GDP is 5%, population growth rate is 0.12%, import growth rate is 5%, and proportion of import covered by export is 2.5% during the period of 2013-2035. The obtained results are compared to Turkey 2013 Energy Report in Table 6 and Figure 2.

Scenario 3: It is assumed that the average growth rate of GDP is 4%, population growth rate is 0.09 %, import growth rate is 4%, and export growth rate 2% during the period of 2013-2035. The obtained results are compared to WEC-TNC Turkey 2013 Energy Report in Table 6 and Figure 3.

In Table 7, energy demand estimations which was done in some years according to WEC-TNC Turkey Energy Report 2013 are seen [2]. The graphics in Figures (1-3) is obtained as a result of a comparison in Table 7.

Table 6. Energy demand estimation between 2013 and 2035 years according to scenarios (1-3) in MTOE.

Years	Scenario 1 (MTOE)		Scenario 2 (MTOE)		Scenario 3 (MTOE)	
	TLBOEDL	TLBOEDQ	TLBOEDL	TLBOEDQ	TLBOEDL	TLBOEDQ
2013	118,8	122,8	120,8	124,7	114	116,1
2014	122,5	127,4	124,9	129,7	116,9	119,6
2015	126,4	132,2	129,1	135	120	123,3
2016	130,4	137,2	133,5	140,5	123,2	127,1
2017	134,5	142,4	138,1	146,1	126,5	131,1
2018	138,8	147,7	142,9	152	129,8	135,1
2019	143,3	153,1	147,9	158,1	133,3	139,3
2020	147,9	158,7	153,1	164,3	136,9	143,6
2021	152,6	164,5	158,5	170,7	140,7	148
2022	157,6	170,3	164,1	177,3	144,5	152,5
2023	162,7	176,2	169,9	183,9	148,5	157,1
2024	168,1	182,2	176	190,5	152,6	161,7
2025	173,6	188,1	182,4	197,2	156,8	166,5
2026	179,4	194,1	189	203,8	161,2	171,2
2027	185,3	200	196	210,3	165,7	176
2028	191,5	205,8	203,2	216,6	170,4	180,9
2029	198	211,4	210,7	222,5	175,3	185,7
2030	204,7	216,8	218,6	228,1	180,3	190,4
2031	211,6	221,8	226,8	233,1	185,5	195,1
2032	218,9	226,4	235,4	237,4	190,9	199,6
2033	226,4	230,5	244,4	240,8	196,5	204
2034	234,2	233,9	253,8	243,1	202,3	208,1
2035	242,3	236,5	263,6	244,1	208,2	212

Table 7. Energy supply and demand estimations realized according to WEC-TNC Turkey Report 2013 [2].

Years	Estimated energy demand (MTOE) (WEC-TNC) [2]
2015	129
2020	146
2023	157
2025	165
2030	185
2035	208

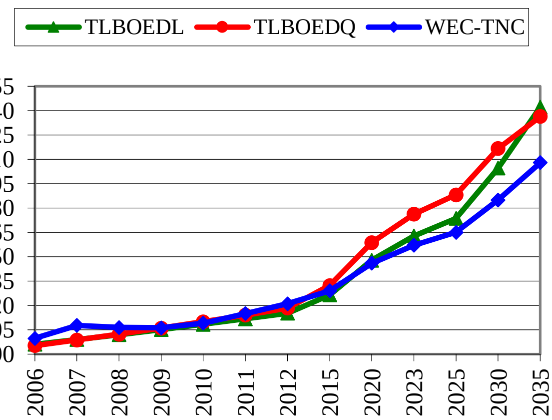

Figure 1. Energy demand estimations realized between 2006 and 2035 years according to scenario 1 in MTOE.

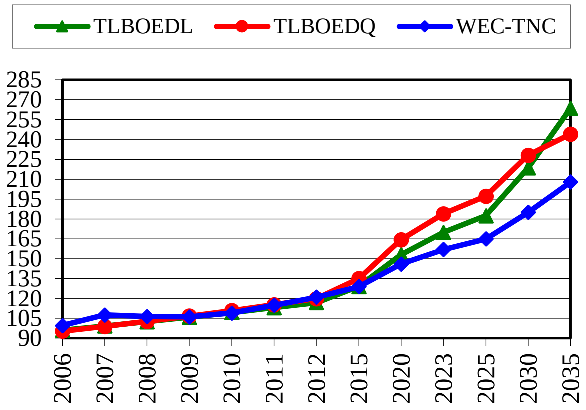

Figure 2. Energy demand estimation realized between 2006 and 2035 years according to scenario 2 in MTOE.

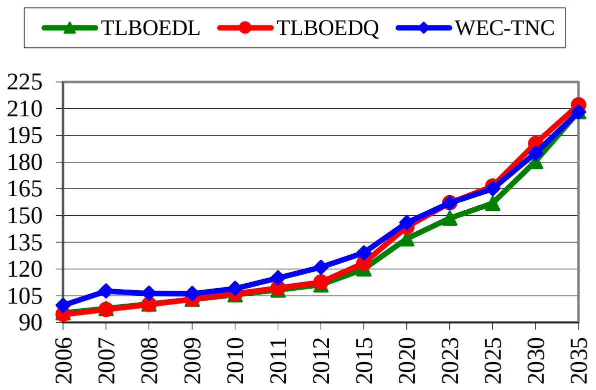

Figure 3. Energy demand estimation realized between 2006 and 2035 years according to scenario 3 in MTOE.

5. Conclusion

Countries must balance the energy supply and demand. Therefore they make agreements between them. Our country is a foreign dependent country as energy sources. This dependency is obliged us to an appropriate and consistent energy policy with the other countries. Energy demands according to Country needs will contribute the savings to the national economy. Excessive deviations in estimating country demands will result the much more natural gas import so the dependency in energy will be risen. In this study, TLBOEDL and TLBOEDQ models make a demand estimation in accordance with given scenarios and these models can be useful in estimation analysis. Especially scenario 3 with its two models is consistent with WEC-TNC Turkey Energy Report 2013.

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