A GENERAL EQUILIBRIUM ENERGY-ECONOMY MODEL FOR TURKEY

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Abstract

With the immense rise of pollutant emissions in recent decades and concomitant global warming, energy policy modeling has become highly important due to the need for policy analysis in order to satisfy the targets and timetables proposed by various international agreements. In this study, energy models for Turkey in order to evaluate various policy alternatives will be proposed. For the present, use of nuclear power plants analyzed together with the assessment of the economic impacts. In the next step, abatement investments, taxes and quotas on Green House Gases (GHGs) will be analyzed together with the assessment of the economic impacts of these policies. We study an energy model which not only represents a detailed energy sector, but also has the ability to capture policy impacts in a single framework. This requires an interdisciplinary study, i.e., expert knowledge of operations researchers in mathematical modeling and the expertise of economists in general equilibrium modeling.

Keywords: Energy modeling, optimization, general equilibrium modeling, environment, policy analysis.

1 Introduction

The literature on energy modeling dates back to nineteen-seventies, following sharp increases in energy costs. The two events causing these sharp increases in energy prices were Yom Kippur War and the resulting Arab Oil Embargo in 1973 and the start of Iran-Iraq War in 1979. The studies on energy issues up to seventies were mainly demand analysis and forecasting. GDP growth rate is considered as the primary determinant of energy demands in these studies and models describing energy demands as exogenous input variables are solved to minimize the costs of energy supply. This treatment worked plausibly well in the 1950-70 era when there was a smooth, continuous progress in energy costs.

Soon it was realized that energy policy measures should be studied in an economy-wide framework in order to represent the interaction between energy sector and the rest of the economy. First attempts were partial equilibrium models describing GDP growth rate as an exogenous input variable and representing a one-way linkage between energy and the rest of the economy. Three of the seven techno-economic models, The Project Independence Evaluation System (PIES) [1], The Baughman-Joskow Regionalized Electricity Model (REM) [2] and The Kennedy World Oil Model [3], discussed in the survey paper [4], are examples of partially equilibrium models. The Energy Technology Assessment (ETA) [5] is another partial equilibrium model employed primarily in the nuclear power debate in the U.S.. In ETA, GDP growth is determined by the labor force and per capita productivity considerations, then the effects of rising energy costs and limited supplies on the growth rate of the GDP cannot be represented, as is the case for the other partial equilibrium models. General equilibrium models, on the other hand, allow for two-way linkage between energy sector and the rest of the economy, i.e., substitution and complementarity relations exist not only among the energy alternatives, but also between the energy alternatives and the other factors of the economy. Well-known among these types of models is Manne's ETA-Macro [6]. Güven [7], which is the main reference of this study, is closely related to ETA-Macro.

The aim of this study is to build energy models for Turkey in order to evaluate various policy alternatives by exploring different modeling strategies. In the first step, the model formulated by Güven [7], is reformulated using up-to-date data. 2003 is taken as the base year for the new model and the model is reformulated considering the current energy profile of Turkey. Different from [7], foreign and domestic consumption goods are modeled as imperfect substitutes. Exchange rate, which is the key factor in foreign trade is also embedded into the model as a parameter. This helps to analyze not only the effects of changes in world energy prices, but also the effects of sharp changes in the exchange rate .The model formulated in this part of the study represents a one-sector economy. The next step is to increase the number of sectors in order to increase representation capability of the model.

Besides the interdependencies between energy and economy, there is a close relationship between environment and the production and consumption activities. The effects of pollutant emissions on the ecological balances have reached to significant levels in the last decades. The Intergovernmental Panel on Climate Change (IPCC), established in 1988 by two United

Nations organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), recently declared in Paris that global warming was "very likely" man-made, which was the strongest conclusion to date. Again, they declared in Bangkok that global warming is solvable but this will be possible only if governments act decisively. All these environmental issues increase the importance of energy policy modeling studies all over the world due to the need for policy analysis in order to satisfy the targets and timetables proposed by various international agreements such as Kyoto Protocol (1997). Then, another important issue proposed within the context of this thesis is to integrate the environmental concerns in the proposed models, similar to the studies [8], [9] and [10].

2 Turkish Energy Sector

Turkish energy resources consist of solid fuels, i.e., *lignite, hard coal, asphaltite, wood, animal and plant waste*, crude oil, natural gas, hydraulic, geothermal and wind electricity and geothermal and solar heat. But national resources are very low compared to total energy supply, i.e., national resources add up to 28.34% of total energy supply in 2003. Total reserves of Turkey, i.e., coal reserves, geothermal and hydraulic potential together with the limited crude oil and natural gas reserves, is nearly 1% of world energy resources. Table 1 gives the reserves of primary energy resources of Turkey.

Table 1: Primary energy resource reserves, 2004

	Proven	Probable	Possible	Total
Asphaltite (Mton)	43	29	7	79
Bitumious coal (Mton)	555	1086		1641
Hydraulic (GWh/Year)	127381			127381
Hydraulic (MW/Year)	36260			36260
Crude Oil (Mton)	42.8			42.8
Natural Gas (Billion m^3)	8			8
Natural Uranium (Ton)	9129			9129
Thorium (Ton)	380000			380000
Geothermal-Electricity (MW/Year)	98		412	510
Geothermal-Heat (MW/Year)	3348		28152	31500
Solar-Electricity (MToe)				
Solar-Heat (MToe)				87

Tables 2 shows the general energy balance of Turkey for 2003 which is taken as the base year for the model to be discussed in Section 3. Details of total solid fuels supply and renewable resources can be seen in tables 3 and 4, respectively, [12].

Table 2: General Energy Balance, KToe, 2003.

	Total Solid Fuels	Crude Oil	Natural Gas	Hydro.	Renewable	Electricity	Total
Primary Energy Supply	**28446**	**31806**	**19450**	**3038**	**1215**	**49**	**84005**
Domestic Production	16554	2494	510	3038	1215		23812
Import (+)	12140	34003	18949			100	65192
Export (-)	5	4035				51	4090
Bunker Sales		644					644
Change in Stocks	-244	-99	-9				-352
Statistical Discrepancy		87					87
Generation and Energy Sector	-9113	-5444	-11562	-3038	-81	9267	-19971
Power Plants	-8089	-2201	-11338	-3038	-81	12090	-12658
Cooking Coal Firms	-969						-969
Briquette	11	-13					-3
Oil Refinery		-1718				-145	-1863
Domestic Consumption and Loss	-65	-1511	-224			-2678	-4478
Total Final Energy Consumption	19333	26362	7888	0	1134	9316	64034
Industrial Consumption	11570	6449	4360		119	4429	26927
Iron and Steel	2126	440	0			756	3322
Chemical-Petrochemical	71	758	326			183	1338
Petrochemical Feedstock		1459					1459
Fertilizer	6	91	420			43	559
Cement	2303	53	52			296	2704
Sugar	371	254	83				708
Non-ferrous metal	89	265	350			219	924
Other Industry	6604	3128	3129		119	2933	15913
Transportation	0	12315	4			77	12396
Railway transportation	0	183	0			77	260
Sea transportation		280					280
Air transportation		906					906
Land transportation		10946	4				10950
Other Sectors	7764	5501	3524		1015	4810	22613
Residential and Services	7764	2729	3524		1015	4495	19527
Agriculture		2772				315	3087
Non-energy		2098					2098

As a developing country, electricity demand of Turkey has been growing rapidly by industrialization and urbanization. Electricity demand of Turkey is met almost by domestic production (which does not mean by domestic natural resources, i.e., Turkish power sector highly depends on imports of fuels used in power stations as mentioned in the previous section). Imports and exports of electricity are in negligible amounts. Table 5 shows the installed capacity values

Table 3: Total Solid Fuels Balance, KToe, 2003.

	Hard Coal	Lignite	Asph.	Second. Coal	Petro. Coke	Wood	Animal and Plant Waste	Total Solid Fuels
Primary Energy Supply	**11283**	**9713**	**0.144**	**381**	**1321**	**4497**	**1251**	**28446**
Domestic Production	1083	9723	0.144			4497	1251	16554
Import (+)	10499			356	1285			12140
Export (-)		5						5
Bunker Sales								
Change in Stocks	-299	-5		25	36			-244
Statistical Discrepancy								
Generation and Energy Sector	-4789	-6362		2038				-9113
Power Plants	-1774	-6315						-8089
Cooking Coal Firms	-2984			2014				-969
Briquette		-13		24				11
Oil Refinery								
Domestic Consump. and Loss	-31	-34						-65
Total Final Energy Consump.	6494	3351	0.144	2419	1321	4497	1251	19333
Industrial Consumption	5861	2103	0.144	2284	1321			11570
Iron and Steel				2126				2126
Chemical-Petrochemical	62	10						71
Petrochemical Feedstock								
Fertilizer		6						6
Cement	868	471			965			2303
Sugar	38	287		46				371
Non-ferrous metal	64	17		9				89
Other Industry	4831	1313	0.144	104	356			6604
Transportation								
Railway transportation								
Sea transportation								
Air transportation								
Land transportation								
Other Sectors	633	1248		135	0	4497	1251	7764
Residential and Services	633	1248		135		4497	1251	7764
Agriculture								
Non-energy								

for years 1980-2006 and Table 6 shows the gross generation values for years 1980-2006, [11].

Diversity in electricity generation has shown great improvement in the last 20 years. Lignite and fuel oil power plants together with hydroelectricity constitute almost all installed capacity with the shares 28%, 13% and 46%, respectively, in 1984. In 2006, on the other hand, these shares decreased to 20%, 5% and 32% although installed capacities of these power stations increased gradually. During this period, most significant evolution has been observed in natural gas power plants. In 1984, there was no natural gas power station generating electricity, but especially after the natural gas agreements in mid 90s, share of natural gas power stations has gradually increased to 28% in 2006.

Table 4: Renewable Resources, KToe, 2003.

	Geothermal Electricity	Wind	Geothermal Heat	Solar Heat	Total
Primary Energy Supply	**76**	**5**	**784**	**350**	**1215**
Domestic Production	76	5	784	350	1215
Import (+)					
Export (-)					
Bunker Sales					
Change in Stocks					
Statistical Discrepancy					
Generation and Energy Sector	-76	-5	0	0	-81
Power Plants	-76	-5			-81
Cooking Coal Firms					
Briquette					
Oil Refinery					
Domestic Consumption and Loss					
Total Final Energy Consumption			784	350	1134
Industrial Consumption				119	119
Iron and Steel					
Chemical-Petrochemical					
Petrochemical Feedstock					
Fertilizer					
Cement					
Sugar					
Non-ferrous metal					
Other Industry				119	119
Transportation					
Railway transportation					
Sea transportation					
Air transportation					
Land transportation					
Other Sectors			784	231	1015
Residential and Services			784	231	1015
Agriculture					
Non-energy					

Electricity market law, issued in 2001, foresees the conduction of market activities predominantly by the private organizations. But, it requires time for the market to come to a liberal and competitive structure since most of the activities are currently performed by state-owned utilities. Although there is significant increase in the share of the production companies and autoproducers, their share is yet 38% of the total installed capacity. Agreements with the production companies imply commitments to purchase. Besides this, high prices foreseen in natural gas agreements (which contain ”take or pay” commitments) and price increases in natural gas and crude oil raise the cost of generating electricity.

Table 5: Installed Capacity in Turkey, MW.

Year	Thermal	Hydro	Geothermal and Wind	Total	Increase (%)
1980	2987.9	2130.8		5118.7	0.0
1981	3181.3	2356.3		5537.6	8.2
1982	3556.3	3082.3		6638.6	19.9
1983	3695.8	3239.3		6935.1	4.5
1984	4569.3	3874.8	17.5	8461.6	22.0
1985	5229.3	3874.8	17.5	9121.6	7.8
1986	6220.2	3877.5	17.5	10115.2	10.9
1987	7474.3	5003.3	17.5	12495.1	23.5
1988	8284.8	6218.3	17.5	14520.6	16.2
1989	9193.4	6597.3	17.5	15808.2	8.9
1990	9535.8	6764.3	17.5	16317.6	3.2
1991	10077.8	7113.8	17.5	17209.1	5.5
1992	10319.9	8378.7	17.5	18716.1	8.8
1993	10638.4	9681.7	17.5	20337.6	8.7
1994	10977.7	9864.6	17.5	20859.8	2.6
1995	11074.0	9862.8	17.5	20954.3	0.5
1996	11297.1	9934.8	17.5	21249.4	1.4
1997	11771.8	10102.6	17.5	21891.9	3.0
1998	13021.3	10306.5	26.2	23354.0	6.7
1999	15555.9	10537.2	26.2	26119.3	11.8
2000	16052.5	11175.2	36.4	27264.1	4.4
2001	16623.1	11672.9	36.4	28332.4	3.9
2002	19568.5	12240.9	36.4	31845.8	12.4
2003	22974.4	12578.7	33.9	35587.0	11.7
2004	24144.7	12645.4	33.9	36824.0	3.5
2005	25902.3	12906.1	35.1	38843.5	5.5
2006	27420.2	13062.7	81.9	40564.8	4.4

In recent years, nuclear energy and renewable energy have gained importance to avoid risks of being highly dependent on natural gas and crude oil imports and to satisfy targets on CO_2 emission levels which are proposed by various international agreements. Turkey has currently no nuclear power plants although building one was brought to agenda many times since 1965. Recently, a law on the establishment and operation of nuclear power plants and energy sales has been approved by the president. MENR of Turkey foresees that 3 nuclear power plants corresponding to a total installed capacity of 5000 MW will be commissioned until 2020.

As seen in table 1, geothermal potential of Turkey is 32010 MW, only 510 MW of which is convenient for electricity generation and 412 MW is possible reserves, i.e., Turkey has very limited geothermal electricity potential. Recent studies conducted by EİE on the wind energy potential, on the other hand, imply that wind energy potential is 20000 MW, 10000 MW of which can be utilized using the current technology.

Table 6: Gross Generation in Turkey, GWh.

Year	Thermal	Hydro	Geothermal and Wind	Total	Increase (%)
1980	11927.2	11348.2		23275.4	3.3
1981	12056.7	12616.1		24672.8	6.0
1982	12384.8	14166.7		26551.5	7.6
1983	16004.1	11342.7		27346.8	3.0
1984	17165.1	13426.3	22.1	30613.5	11.9
1985	22168.0	12044.9	6.0	34218.9	11.8
1986	27778.6	11872.6	43.6	39694.8	16.0
1987	25677.2	18617.8	57.9	44352.9	11.7
1988	19030.8	28949.6	68.4	48048.8	8.3
1989	34041.0	17939.6	62.6	52043.2	8.3
1990	34314.9	23148.0	80.1	57543.0	10.6
1991	37481.7	22683.3	81.3	60246.3	4.7
1992	40704.6	26568.0	69.6	67342.2	11.8
1993	39779.0	33950.9	77.6	73807.5	9.6
1994	47656.7	30585.9	79.1	78321.7	6.1
1995	50620.5	35540.9	86.0	86247.4	10.1
1996	54302.8	40475.2	83.7	94861.7	10.0
1997	63396.9	39816.1	82.8	103295.8	8.9
1998	68702.9	42229.0	90.5	111022.4	7.5
1999	81661.0	34677.5	101.4	116439.9	4.9
2000	93934.2	30878.5	108.9	124921.6	7.3
2001	98562.8	24009.9	152.0	122724.7	-1.8
2002	95563.1	33683.8	152.6	129399.5	5.4
2003	105101.0	35329.5	150.0	140580.5	8.6
2004	104463.7	46083.7	150.9	150698.3	7.2
2005	122242.3	39560.5	153.4	161956.2	7.5
2006	131835.1	44244.2	220.5	176299.8	8.9

3 Model

The model studied is a reformulation of [7], using the up-to-date data and considering the current energy profile of Turkey. The model in [7] is a variation of Eta-Macro [6] which is a general equilibrium model that allows two-way linkage between energy sector and the rest of the economy, i.e., substitution and complementarity relations exist not only among the energy alternatives, but also between the energy alternatives and the other factors of the economy. The model consists of two submodels: macro submodel and energy submodel. The planning horizon is chosen as 2003-2030 and the objective is to compute intertemporal equilibrium solutions by maximizing a discounted utility function which will be explained in the following sections.

3.1 Macro Submodel

The submodel explained in this section is a macroeconomic growth model which allows substitution among capital, labor, intermediates and alternative sources of energy. Energy is represented under four main categories as follows.

- Electricity,
- Petroleum products,
- Natural gas,
- Solid fuels.

The model assumes a one-sector economy, i.e., there is a single production function that generates gross output, Y, using the factors: capital, labor, intermediates and alternative sources of energy. There is a unit elasticity of substitution between capital and labor and among alternative sources of energy. And, overall gross output function is a Constant Elasticity of Substitution (CES) function, i.e., there is a constant elasticity of substitution, $\frac{\sigma-1}{\sigma}$, between capital-labor aggregate, K and L, intermediates, INT and the energy aggregate as seen below.

$$Y \quad = \quad [a_1(K^{sk}L^{sl})^{\rho} + a_2 INT^{\rho} + a_3(E^{se}P^{sp}N^{sng}S^{ss})^{\rho}]^{(\frac{1}{\rho})} \tag{1}$$

where E, P, N and S denote electricity consumption, petroleum products consumption for nonelectric use, natural gas consumption for nonelectric use and solid fuels consumption for nonelectric use, respectively and $sk + sl = 1$ and $se + sp + sng + ss = 1$.

The gross production, Y, also satisfies the following macroeconomic equality.

$$Y \quad = \quad GDP + er \cdot INT + EC \tag{2}$$

where EC denotes the energy costs and er is the exchange rate. GDP satisfies the conventional identity

$$GDP \quad = \quad C + INV + er \cdot (X - M) \tag{3}$$

where INV is the total investments made by domestic and foreign capital goods and, X and M denote exports and imports, respectively.

Total energy costs, consumption and total investment, EC, C and INV, respectively, can be decomposed into domestic and foreign components.

$$EC = ECD + er \cdot ECF \quad (4)$$

$$C = CGD + er \cdot CGF \quad (5)$$

$$INV = INVD + er \cdot INVF \quad (6)$$

Imports consist of investment on foreign goods, $INVF$, payments for intermediates, INT, foreign energy costs, ECF, and payments for consumption goods, CGF.

$$M = INVF + INT + ECF + CGF \quad (7)$$

Then, Equation 2 can be rewritten using the equations 3, 4, 6 and 7 as follows.

$$C = Y - INVD - ECD - er \cdot X + er \cdot CGF. \quad (8)$$

After explaining the macroeconomic framework used in the study, the equations and constraints used in the model can be listed one by one.

It is assumed that production takes place according to a putty-clay technology, i.e., substitution takes place only for the increments in the factors and surviving stock changes occur only due to retirement.

$$K_t = KN_t + \lambda \cdot K_{t-1} \qquad t = 2004, ..., 2030 \quad (9)$$

$$L_t = LN_t + \lambda \cdot L_{t-1} \qquad t = 2004, ..., 2030 \quad (10)$$

$$INT_t = INTN_t + \lambda \cdot INT_{t-1} \qquad t = 2004, ..., 2030 \qquad (11)$$

$$E_t = EN_t + \lambda \cdot E_{t-1} \qquad t = 2004, ..., 2030 \qquad (12)$$

$$P_t = PN_t + \lambda \cdot P_{t-1} \qquad t = 2004, ..., 2030 \qquad (13)$$

$$N_t = NN_t + \lambda \cdot N_{t-1} \qquad t = 2004, ..., 2030 \qquad (14)$$

$$S_t = SN_t + \lambda \cdot S_{t-1} \qquad t = 2004, ..., 2030 \qquad (15)$$

Note that some variables end with an N, which indicates that these values are the incremental values newly added to the stocks. Putty-clay nature is also valid for the gross output as follows.

$$Y_t = YN_t + \lambda \cdot Y_{t-1} \qquad t = 2004, ..., 2030 \qquad (16)$$

where

$$YN_t = [a_1(KN^{sk}LN^{sl})^{\rho} + a_2 INTN^{\rho} + a_3(EN^{se}PN^{sp}NN^{sng}SN^{ss})^{\rho}]^{(\frac{1}{\rho})}$$
$$t = 2004, ..., 2030 \qquad (17)$$

Accumulated investments belonging to the current and the previous period determine the capital increments.

$$KN_t = \frac{2}{3} \cdot INV_{t-1} + \frac{1}{3} INV_t \qquad t = 2004, ..., 2030 \qquad (18)$$

Sum of investments on domestic and foreign goods give the total investment.

$$INV_t = INVD_t + er \cdot INVF_t \qquad t = 2003, ..., 2030 \qquad (19)$$

Imports consist of investment on foreign goods, payments for intermediates, foreign energy costs and payments for consumption goods.

$$M_t = INVF_t + ECF_t + INT_t + CGF_t \qquad t = 2003, ..., 2030 \qquad (20)$$

The foreign exchange constraint can be written as

$$X_t + F_t + W_t \geq M_t \qquad t = 2003, ..., 2030 \qquad (21)$$

where F and W denotes foreign capital inflow and factor incomes from abroad, respectively. And, consumption in period t can be written as

$$C_t = Y_t - INVD_t - er \cdot X_t - ECD_t + er \cdot CGF_t \qquad t = 2003, ..., 2030 \qquad (22)$$

Besides the equations and constraints presented above, it may be appropriate to set some of the variables exogenously or limit them as a proportion of the GDP as follows.

$$F_t \leq LimF \cdot GDP_t \qquad t = 2003, ..., 2030 \qquad (23)$$

$$W_t \leq LimW \cdot GDP_t \qquad t = 2003, ..., 2030 \qquad (24)$$

$$INV_t \geq InvLOW \cdot GDP_t \qquad t = 2003, ..., 2030 \qquad (25)$$

$$INV_t \leq InvUP \cdot GDP_t \qquad t = 2003, ..., 2030 \qquad (26)$$

where $LimF$, $LimW$, $InvLOW$ and $InvUp$ are the associated limiting parameters.

The objective of the model is to compute intertemporal equilibrium solutions by maximizing the following discounted utility function.

$$Obj = \qquad max(\sum_{2003}^{2030}(1-\Delta)^{t-2003} \cdot (logCGD_t^{scgd}) + logCGF_t^{scgf})+$$
$$(1-\Delta)^{28} \cdot (\frac{1}{\Delta}) \cdot (logCGD_{2030}^{scgd} + logCGF_{2030}^{scgf}). \qquad (27)$$

where Δ is the discount factor and $scgd$ and $scgf$ are share parameters for domestic and foreign consumption goods, respectively. Note that the terms for years beyond 2030 are assumed to be the same as the values for 2030.

3.2 Energy Submodel

Energy consumption is divided into four categories as mentioned in the beginning of the section. These are electricity, petroleum products, natural gas and solid fuels. All energy related variables and parameters are defined in terms of a unit energy measure, KToe.

Seven technologies are assumed for electricity generation as follows.

- Hydroelectric power plants,

- Lignite power plants,
- Petroleum products power plants,
- Coal power plants,
- Natural gas power plants,
- Renewable resources,
- Nuclear power plants.

Assumptions used in the energy submodel can be listed as below.

- Solid fuels consist of coal, lignite and wood.
- Domestic production of natural gas is ignored.
- Only imported hard coal is assumed to be used in coal power plants.
- Only imported petroleum products are assumed to be used in petroleum products power plants.
- A thirty year plant life is assumed for the power plants and it is assumed that only the initial installed capacity is depreciated during the planning horizon, i.e., new installed capacity is not depreciated. A linear depreciation function is assumed, i.e., installed capacity declines annually by 1/30 of the initial capacity due to the retirement.

The link between the two submodels are provided by the energy demand and cost relations as shown below symbolically.

$$[E_t, P_t, N_t, S_t] = [A_t][z_t] \tag{28}$$

$$[ECD_t, ECF_t] = [B_t][z_t] \tag{29}$$

where $[A_t]$ and $[B_t]$ are the associated technology and cost matrices for the energy system, and $[z_t]$ represents the energy activities.

4 Data and Numerical Experiments

As mentioned in the previous chapter, all energy related variables are expressed in terms of a unit energy measure, KToe. The general energy balance data used in the model can be seen in Table 7 which is a modified version of tables 2, 3 and 4.

4.1 Energy Cost Parameters

The following points about cost parameters plants are noteworthy.

- All cost parameters are estimated in terms of year 2003 10^{12} TL.
- Cost parameters for the power plants are obtained from Seyhan [13].
- Investment costs which are available in terms of cost per MW are converted to cost per unit energy considering the energy generated by a 1-MW power plant over a lifetime of 30 years.
- All cost figures in terms of foreign currency are first converted into year 2003 value of corresponding currency. Then this values are converted into TL using 2003 exchange rates. 1$ is taken as 1.5 million TL on the average for 2003, [14]. er is assumed to be 1 throughout the planning horizon.
- Electricity transmission and distribution costs are excluded.
- Costs of solid fuels are minemouth costs.
- Domestic oil costs are obtained from Turkish Statistical Institute TÜİK.
- Foreign oil, natural gas and coal prices are estimated using the projections in [15], [16] and [17].

Table 7: General Energy Balance Used in the Model, KToe, 2003.

	Lignite	Hard Coal	Wood	Total Solid	Petroleum Products	Natural Gas	Hydro	Renew.	Elec.	Total
Energy Supply	9713	11664	5748	27125	33127	19450	3038	81	49	82871
Domestic Production	9713	1055	5748	16516	2173		3038	81		21810
Imports		10609		10609	30953	19450			49	61061
Generation and Energy Sector	-6349	-1805		-8154	-3712	-11562	-3038	-81	9412	-17136
Power Plants	-6315	-1774		-8089	-2201	-11338	-3038	-81	12090	-12658
Own use and Loss	-34	-31		-65	-1511	-224			-2678	-4478
Sector Aggregates	3364	9859	5748	18971	29414	7888			9461	65735
Industrial Consumption	2103	8146		10249	7770	4360			4429	26808
Iron and Steel		2126		2126	440				756	3322
Chemical-Petrochemical	10	62		71	758	326			183	1338
Petrochemical Feedstock					1459					1459
Fetilizer	6			6	91	420			43	559
Cement	471	868		1339	1017	52			296	2704
Sugar	287	84		371	254	83				708
Non-ferrous metal	17	73		89	265	350			219	924
Other Industry	1313	4934		6248	3484	3129			2933	15794
Transportation					12315	4			77	12396
Railway transportation					183				77	260
Sea tansportation					280					280
Air transportation					906					906
Land transportation					10946	4				10950
Other Sectors	1260	744	5748	7752	5512	3524			4810	21598
Residental and Services	1260	744	5748	7752	2741	3524			4495	18512
Agriculture					2772				315	3087
Oil Refinery + Other	1	969		971	1720				145	2835
Non-energy					2098					2098
Electricity Generation (GWh)	23590	8663		32253	9196	63536	35330	150	140465	
Installed Capacity (MW)	6439	1800		8239	3203	11505	12579	34	47001	

4.2 Macroeconomic Data

Base year values for macroeconomic variables used in the model are tabulated in Table 8, and the following items are to give information about this data.

Table 8: Macroeconomic Data, 10^{12} TL, 2003.

Consumption	C_{2003}	288590.40
Capital Formation	INV_{2003}	55618.335
Domestic	$INVD_{2003}$	37596.38
Foreign	$INVF_{2003}$	18021.954
Exports	X_{2003}	98496.34
Imports	M_{2003}	109539.72
Energy	ECF_{2003}	18353.59
Intermediates	INT_{2003}	61517.16
Consumption Goods	CG_{2003}	11647.02
Foreign Investment Goods	$INVF_{2003}$	18021.95
GDP	GDP_{2003}	333165.35
Factor Incomes from Abroad	W_{2003}	1095
Foreign Capital Inflows	F_{2003}	2628
Domestic Energy Costs	ECD_{2003}	3741.08
Total Capital Stock	K_{2003}	1013516.54
Gross Output	Y_{2003}	416777.18

- Domestic and foreign energy costs are determined by the model using cost and activity parameters mentioned in the previous section.
- Estimates in [18] is used for total capital stock.
- Data for foreign capital inflows is obtained from [19].
- All remaining data is provided from (TÜİK).

4.3 Preliminary Results

The model is coded in GAMS 20.0 and MINOS5 is used as the solver. The model is solved only for the base case and for the alternative scenario where three 5000 MW nuclear power plants join the electricity generation system by the years 2012, 2014 and 2015, respectively. The nuclear scenario is the same as the one used by MENR for electricity demand projections.

The key parameter that triggers a macroeconomic growth model is the labor growth rate for which population growth rate estimates of TÜİK are used in the model. On the other hand, scale parameter in CES function which represents the technical progress also has an important role in development of the economy. This parameter is assumed to be 1% throughout the planning horizon. A list of parameter values used in the model is given in Table 9.

Table 9: Parameter values

sk	0.75
sl	0.25
se	0.314
sp	0.422
sng	0.116
ss	0.148
$scgd$	0.96
$scgf$	0.04
σ	0.45
λ	0.97
Δ	0.10

Other parameters those affect the solutions are the cost parameters that change over time such as crude oil, natural gas and foreign coal prices. Estimation of these parameters is explained in 4.1.

Table 10: Base Case: Macroeconomic Variables , Year 2003 10^{12} TL

Year	GDP	C	INT	INV	M	X	CG	ECF
2003	333165.40	288590.40	61517.16	55618.33	109539.70	98496.34	11647.02	18353.59
2010	505629.70	386806.70	155486.50	146632.60	256572.00	228762.40	15606.20	39972.64
2015	709974.20	543130.30	246026.60	205892.50	380253.10	341204.60	21857.81	48471.03
2020	980182.50	749839.60	358612.00	284252.90	540388.20	486478.20	30294.72	63265.06
2030	1690574.00	1411630.00	632480.40	371926.40	923727.40	830745.80	57151.42	115755.30

As seen from the tables 10, 11, 12 and 13, preliminary numerical results show that the nuclear scenario does not make significant effect on the macroeconomic and energy balances. Share of the electricity in the final energy usage increase just after the nuclear power plants start generation. But, this effect become negligible in the long-run.

Table 11: Nuclear: Macroeconomic Variables , Year 2003 10^{12} TL

Year	GDP	C	INT	INV	M	X	CG	ECF
2003	333165.40	288590.40	61517.16	55618.33	109539.70	98496.34	11647.02	22094.67
2010	505644.20	386817.80	155512.00	146636.80	256590.90	228780.50	15611.39	43179.81
2015	712708.40	545221.90	246906.80	206685.40	379373.40	340174.40	22006.98	51539.25
2020	983825.00	752626.10	359452.30	285309.30	540049.40	485939.10	30425.82	68168.08
2030	1737115.00	1450491.00	649000.80	382165.40	943301.70	847760.40	58649.79	128995.60

Table 12: Base Case: Energy Variables, KToe

Year	E	P	S	N	Total Primary Energy	Final Energy
2003	12079.96	29414.28	18971.17	7888.37	82753.12	68353.78
	17.67%	43.03%	27.75%	11.54%		
2010	18926.38	37997.05	32917.89	15458.80	125750.40	105300.10
	17.97%	36.08%	31.26%	14.68%		
2015	25576.62	52242.71	49229.61	20143.99	175109.80	147192.90
	17.38%	35.49%	33.45%	13.69%		
2020	35504.40	69111.39	71151.66	25915.73	240006.20	201683.20
	17.60%	34.27%	35.28%	12.85%		
2030	65246.82	108080.89	117730.14	39978.02	410160.50	331035.90
	19.71%	32.65%	35.56%	12.08%		

Table 13: Nuclear Scenario: Energy Variables, KToe

Year	E	P	S	N	Total Primary Energy	Final Energy
2003	12079.96	29414.28	18971.17	7888.37	82753.12	68353.78
	17.67%	43.03%	27.75%	11.54%		
2010	18827.76	37998.08	33505.58	15333.72	125961.90	105665.10
	17.82%	35.96%	31.71%	14.51%		
2015	31213.49	50685.78	49080.17	19495.72	166010.00	150475.10
	20.74%	33.68%	32.62%	12.96%		
2020	40429.07	67643.46	72336.62	25335.68	229570.60	205744.80
	19.65%	32.88%	35.16%	12.31%		
2030	70158.66	109170.93	122138.04	40533.63	406162.00	342001.30
	20.51%	31.92%	35.71%	11.85%		

5 Conclusion And Future Work

A one-sector general equilibrium energy economic model has been formulated and some preliminary results were obtained in this part of the study. Only, impacts of use of nuclear power has been analyzed for the time being.

Based on the very limited numerical experiments, nuclear scenario that MENR uses in electricity demand projections has insignificant does not effect the national macroeconomic and energy balances significantly. In fact, according to recent official declarations, MENR plans to commission 3 nuclear power plants corresponding to a total installed capacity of 5000 MW, which is lower than the assumptions used in the projections, until 2020. As a result, in order to benefit from nuclear power, a more comprehensive plan should be presented considering the risks associated with the nuclear power generation.

A step further is to incorporate the environmental aspects into the model and abatement investments, taxes and quotas on Green House Gases (GHGs) will be analyzed together with the assessment of the economic impacts of these policies. Then, it is planned to extend the current model to a multi-sector model, again in the optimization framework which will help us to have a better representation of the economy.

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