Diffusion Potential of New Energy Efficient Technologies Under an Uncertain Environment

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ABSTRACT

The main purpose of this paper is to improve energy efficiency in the final energy consumption of Turkey over a short term period. The overall mission of this paper therefore focus on the model that serves as the basis for establishing a reference projection of Turkey on energy use, economic growth and emission reduction by giving concern on energy efficient technologies. Model is designed so that critical decisions such as efficiency investments and emission restrictions are based upon on the financial burden of them on economies. This paper, giving attention to the economical and energy-emission policy aspects, aims to analyze the relationships among the main energy demanding sectors, investments on new and energy efficient technologies, financial burden, and CO2 emissions.

Keywords: Aggregate Economic Equilibrium Modeling; Energy Efficiency; Emission Restriction.

1. INTRODUCTION

Modern development today is very much dependent on the availability of huge amounts of energy. According to some experts (IEA), world energy consumption is expected to be 40% higher in 2020 than it is today. If no action is taken, these trends are likely to lead to supply interruptions, security risks of fossil fuel dependence, and price shocks caused by limited fossil fuel resources. Moreover, current level and profile of energy production contributes to the enormous emissions of carbon dioxide (and other greenhouse gases) into the atmosphere, leading to the likelihood of serious climate changes in the not too distant future.

Turkey's energy and electricity consumptions, over the period 1990-2004, have grown at an annual rate of 3.7% and 7.2% respectively. At the same period, GDP growth rate was 1.3%. In 2004, oil had the largest share of total final energy consumption with 37% while natural gas followed it with 23%. Hard coal, lignite and renewables (including hydroelectricity) also contributes energy consumption with shares of 16%, 11%, and 13% respectively.

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Transportation, industrial, and household/service sectors are the main energy demanding sectors of Turkey. The percent of transportation sector in the total final energy consumption was 20% in 2004 while the share of industrial sector was 42%. The household/service sector share, moreover, increased 36% in the period 1990-2004. With these consumption patterns, it is clear that it has vital importance to explore the ways of consuming energy in efficient manners. Therefore, it is significant to examine the Turkey's potential for energy efficient technologies in satisfying its energy demands without damaging economy and also with a special focus on reducing the emissions.

The main purpose of this paper is to improve energy efficiency in the final energy consumption of Turkey. The overall mission of this paper therefore focus on the model that serves as the basis for establishing a reference projection of Turkey on energy use, economic growth and emission reduction by giving concern on energy efficient technologies.

This paper, giving attention to the economical and energy-emission policy aspects, aims to analyze the relationships among the main energy demanding sectors, investments on new and energy efficient technologies, financial burden, and CO_2 emissions.

2. LITERATURE SURVEY

Economic equilibrium models are grouped under two approaches: top-down approaches and bottom-up approaches. Aggregate Economic Equilibrium (AEE) models (Hogan and Manne, 1979) are classified under the top-down approach. They describe investment and consumption patterns, and emphasize short-run energy policy dynamics. Final demand determines the size of the economy and the models work to balance quantity based on exogenous prices. However, the economy representation is aggregate. Typically, there is an economy-wide production function, generally in CES(Constant Elasticity of Substitution)-form, relating capital (*K*), labor (*L*), energy (*E*) and other inputs (*O*) to produce gross output (*Y*), i.e. $Y=f(K,L,E,O)$. Gross output is also computed as the sum of energy costs (*EC*) and *GDP*, i.e. $Y=EC+GDP$. The addition of *EC* to *GDP* involves double counting (as *GDP* accounting already includes the cost of energy) in order to feature an accounting of energy-economy interactions. However, the effect of the double counting is in a way penalized by the inclusion of energy as an explicit factor of production. Hence, energy costs enter only indirectly into gross production. Although this approach is not fully satisfactory from an economic point of view, it provides a fairly well representation of the two-way linkage between the energy sector and the rest of the economy. The production function parameters are determined from optimality conditions to maximize the profit of producers for a representative year. Consumer utility maximization, on the other hand, is envisaged in the overall objective function. That's how both parties are taken care of so that the model yields an aggregate economic equilibrium.

The literature covers various macroeconomic models using the AEE approach for energy and environmental policy modeling. These include MERGE (Manne et al., 1995), CETA (Peck/Teisberg, 1992), MARKAL-MACRO (Manne and Wene, 1992), NEMS (Hoffman/Stephan, 1996), GLOBAL 2100 (Manne and Richels, 1994), MIS (Kuckshinrichs/Kemfert, 1997), RICE (Nordhaus/Yang, 1996), and GRAPE (Kurosawa et al., 1999), among others.

In this study we make use of elasticity of substitution in production function among main energy demanding sectors (e.g. transport, household&service, industry). Electricity and non-electricity energy are the two different inputs of gross output while in each of these two inputs substitution among three different sectors (both for electricity and non-electricity) are allowed. This allows us to model the effects of energy efficient technologies on each energy demanding sector.

3. PROBLEM DEFINITION

The purpose of this study is to model the *structure* that reflects the effects of transition from old technologies to energy efficient technologies on economy. The model is constructed under three sub models: energy, economy, and environment. Capacity and gross output are depreciated with fixed amounts. Transition between old and new technologies, so the increase in sectoral efficiency index, depends on the financial burden of the energy consumption. The aim is to decrease energy consumption cost and improve economic variables by satisfying the demand with more efficient technologies (which cover the same demand with less energy consumption). In the efficiency improvement scenario, efficiency index is fixed 100 in the base year. Any increase in index value (a value more than 100) reflects the fact that new capacity additions will be less energy efficient and vice versa. Unit energy prices (resource based) are used as the constant and exogenous variables of the model.

The effect of most of the variables in the model occurs in very short time periods. The economic variables increase immediately as efficiency goes down which reflects an improvement in efficiency. Therefore, the time unit is chosen as year for this study and time horizon is determined as 8 years.

4. MODEL FORMULATION

4.1. Model Structure

In this research, an integrated energy-economy-environment model is developed and calibrated to explore the diffusion prospects and integration opportunities of energy efficient technologies on different energy technologies in Turkey. There are three sub models in the model: energy, economy, and environment. The model aggregates energy demands, capital requirements and labor inputs under an economy-wide nested constant elasticity of substitution (CES) production function. Energy demands are separated into electric and non-electric energy as two broad categories of secondary energy forms. The demand side includes a detailed representation of energy consumption figures via detailed representation of transportation, industry, and household/service sectors. Supplies and demands are equilibrated within each time period, thereby having inter temporal interaction as a result of the savings-investment accumulation process inherent in the model formulation.

The associated environmental sub model includes feedback links both to the energy sector and the economy over a ten-year planning horizon. Model design and construction is based upon following principles and assumptions:

The sub models are linked to obtain equilibrium solutions through utility maximization over a planning horizon of T periods. In consistence with the conventional theory of consumption, utility is defined as the totality of the discounted logarithm of consumption.

Production (see Eq.1) is described within a nested structure of an economy-wide neoclassical production function aggregating electricity service demands in three sub sectors (transport(TE_t), household&service(HE_t), industry(IE_t)), non-electricity service demands in three sub sectors (transport(TNE_t), household&service(HNE_t), industry(INE_t)), and primary factors (K_t, L_t) at a constant elasticity of substitution (the elasticity of substitution between the primary factors, electricity demands, and non-electricity demands being constantly $\sigma = 1/(1-\rho)$). Electricity and non-electricity come up from the aggregation of electricity demand in transport sector (TE_t), household&service sector (HE_t), and industry sector (IE_t) and the aggregation of non-electricity demand in transport sector (TNE_t), household&service sector (HNE_t), and industry sector (INE_t) at a unitary elasticity of substitution (Cobb-Douglas), respectively. Capital (K_t) and labor (L_t) are also combined in Cobb-Douglas form to yield the primary aggregates. Substitution is allowed only among newly added variables whereas the remaining stocks remain unchanged.

$$YN_t = \gamma_t \left[\alpha_t \left[KN_t^{sk} . LN_t^{sl} \right]^{\rho} + \beta_t \left[TEN_t^{ste} . EN_t^{she} . IEN_t^{sie} \right]^{\rho} + \omega_t \left[TNEN_t^{stne} . NEN_t^{shne} . INEN_t^{\sin e} \right]^{\rho} \right]^{1/\rho} \quad (1)$$

Total electricity and non-electricity consumptions regarding the sectors are further balanced to the total electricity and non-electricity consumptions regarding the resources (e.g. hard coal, lignite, oil, natural gas, geothermal, etc.)

Efficiency Index affects the efficiency levels of new capacity additions. Transition between old and new technologies, so the increase in sectoral efficiency index, depends on the financial burden of the total energy consumption. The aim is to decrease energy consumption cost and improve economic variables by satisfying the same demand with more efficient/less energy consumed technologies. Efficiency is improved until the marginal cost of efficiency improvement equals to the marginal cost of energy consumption. In the base scenario efficiency index values are eliminated from the model equations and not used as a variable that may affect the system. However, in the efficiency improvement scenario, efficiency index is fixed 100 in the base year. Any increase in index value (a value more than 100) leads to less energy efficient technologies in newly added capacities and any decrease in index value (a value less than 100) improves the energy efficiency in newly added capacities. Average efficiency index value of a sector is obtained from the ratio energy consumption to energy demand. These values are further equated to the average values coming from the weighted average of newly added efficient capacity and the efficiency of remaining capacity from the previous period. Energy consumption cost, the main component of the total energy cost, comes from the multiplication of each resource based energy type with its unit price (YTL/Gwh). The costs of efficiency improvements are included in the total energy cost which has a direct impact on GDP and consumption. Total CO2 emission is calculated by multiplying each energy consumption figures of resources with the corresponding emission factors. In the CO2 emissions scenario, an emission restriction level of CO2 emission is applied and any deviation from this restriction level is penalized with a unit cost (YTL/ton CO2). CER/VER (Certified Emission Reduction / Verified Emission Reduction) Prices are used as indicators of this deviation cost. The CO2 emission cost is also used as a component of total energy cost. In base scenario, this cost is fixed to zero while in CO2 emission scenario applied to decrease emission by putting an extra financial burden on economic variables.

Model horizon is kept short since our main objective is to cover possible responses of economy and energy compositions of Turkey in near 8-10 year horizon with possible policy implementations such as efficiency improvement and emission restriction level. Also short time horizon includes some advantages such as possible model simplifications. This may become important in the long run such as emission factor of energy used by the sector which is currently determined by historical data and possible future trends. Exogenous variables are obtained analyzing the past five-year data of each sector.

4.2. Definitions of Variables

U(T) Utility: This is the objective function of general equilibrium model. It represents the satisfaction of the consumers form the economic and related activities with the interaction of energy subsectors.

C(T) Consumption: C is **general** consumption in the economy. This includes most personal expenditures of households such as food, rent, medical expenses. Also government expenditures are included under this category for the model. It is measured as 87' fixed prices YTL.

GDP(T) Gross Domestic Product : GDP is defined as the total market value of all final goods and services produced within a given country in a given period of time (usually a calendar year). It is also considered the sum of value added at every stage of production (the intermediate stages) of all final goods and services produced within a country in a given period of time, and it is given a money value. It is measured as 87' fixed prices YTL.

I(T) Investment : I is defined as investments by business or households in capital. Examples of investment by a business include construction of a new mine, purchase of software, or purchase of machinery and equipment for a factory. Spending by households on new houses is also included in Investment. It is measured as 87' fixed prices YTL.

X(T) Export: X is gross exports. GDP captures the amount a country produces, including goods and services produced for other nations' consumption, therefore exports are added. It is measured as 87' fixed prices YTL.

M(T) Import: M is gross imports of the country. It is measured as 87' fixed prices YTL.
Y(T) Gross Output: It is equal to the value of net output or GDP (also known as gross value added) *plus* intermediate consumption. For our case it is defined as GDP plus total electricity consumption cost. It is measured as 87' fixed prices YTL.

TECC(T) Total Energy Consumption Cost: This the cost of energy including pure consumption, efficiency improvement cost and CO2 emission costs. It is the most important variable connecting general economic activity and energy related activities. It is measured as 87' fixed prices YTL.

EFFC(T) Efficiency Improvement Cost: EFF is the sum of efficiency improvement activity costs under electricity and non-electricity energy sectors with subdivisions Transport, Household and Industry. It is measured as 87' fixed prices YTL.

ECC(T) Energy Consumption Cost: ECC is the sum of all energy consumption cost related to economic activities. Mainly it is subdivided into electricity and non-electricity where each sector is composed of subsectors Transport, Household and Industry. It is measured as 87' fixed prices YTL.

CO2C(T) CO2 Emission Cost: CO2C is the sum of costs resulting from the deviation of emitted CO2 from the energy related activities within the economy from the target values. It is dependent on which primary resources used to satisfy the demand and under which efficiency levels the demand is satisfied. It is measured as 87' fixed prices YTL.

TEFFC(T) Efficiency Improvement Cost in Electricity – Transport: TEFFC is the cost of efficiency improvement in Transportation sector subject to electrical energy consumption. It is measured as 87' fixed prices YTL.

HEFFC(T) Efficiency Improvement Cost in Electricity – Household: TEFFC is the cost of efficiency improvement in Household sector subject to electrical energy consumption. It is measured as 87' fixed prices YTL.

IEFFC(T) Efficiency Improvement Cost in Electricity – Industry: TEFFC is the cost of efficiency improvement in Industrial sector subject to electrical energy consumption. It is measured as 87' fixed prices YTL.

TNEFFC(T) Efficiency Improvement Cost in Non-Electricity – Transport: TEFFC is the cost of efficiency improvement in Transportation sector subject to electrical energy consumption. It is measured as 87' fixed prices YTL.

HNEFFC(T) Efficiency Improvement Cost in Non-Electricity – Household: TEFFC is the cost of efficiency improvement in Transportation sector subject to electrical energy consumption. It is measured as 87' fixed prices YTL.

INEFFC(T) Efficiency Improvement Cost in Non-Electricity – Industry: TEFFC is the cost of efficiency improvement in Transportation sector subject to electrical energy consumption. It is measured as 87' fixed prices YTL.

YN(T) Incremental Gross Output: YN(T) is the addition to the gross output of the previous year forming this years Y(T). It is measured as 87' fixed prices YTL.

K(T) Capital : K is the capital which is the money that can be used for investment activities. It is measured as 87' fixed prices YTL.

KN(T) Incremental Capital : KN is the change of K with respect to previous year. It is measured as 87' fixed prices YTL.

E(T) Electricity Demand: E is the electricity demanded by the economy in present year. It is measured as Gwh.

NE(T) Electricity Demand: NE is the non-electricity energy demanded by the economy in present year. It is measured as Gwh.

TE(T) Electricity Demand in Transport Sector: TE is the electricity demanded by transportation sector in present year. It is measured as Gwh.

HE(T) Electricity Demand in Household Sector: HE is the electricity demanded by household sector in present year. It is measured as Gwh.

IE(T) Electricity Demand in Industrial Sector: IE is the electricity demanded by industrial sector in present year. It is measured as Gwh.

TNE(T) Non-Electricity Demand in Transport Sector: TNE is the non-electricity energy demanded by transportation sector in present year. It is measured as Gwh.

HNE(T) Non-Electricity Demand in Household Sector: HNE is the non-electricity energy demanded by household sector in present year. It is measured as Gwh.

INE(T) Non-Electricity Demand in Industrial Sector: INE is the non-electricity energy demanded by industrial sector in present year. It is measured as Gwh.

TEN(T) Incremental Electricity Demand in Transport Sector: TEN is the new electricity demanded by transportation sector with respect to past year. It is measured as Gwh.

HEN(T) Incremental Electricity Demand in Household Sector: HEN is the new electricity demanded by household sector with respect to past year. It is measured as Gwh.

IEN(T) Incremental Electricity Demand in Industrial Sector: IEN is the new electricity demanded by industrial sector with respect to past year. It is measured as Gwh.

TNEN(T) Incremental Non-Electricity Demand in Transport Sector: TNEN is the new non-electricity energy demanded by transportation sector with respect to past year. It is measured as Gwh.

HNEN(T) Incremental Non-Electricity Demand in Household Sector: HNEN is the new non-electricity energy demanded by household sector with respect to past year. It is measured as Gwh.

INEN(T) Incremental Non-Electricity Demand in Industrial Sector: INEN is the non-electricity energy demanded by industrial sector with respect to past year. It is measured as Gwh.

W(T) Workers Remittances: W is the monet transferred by the workers outside the country to the economy. It is measured as 87' fixed prices YTL.

TR(T) Tourism: T is the money received by touristic activities within country. It is measured as 87' fixed prices YTL.

OT(T) Other Income from abroad: OT is the money that is gained by economy that can not categorized under W or TR. It is measured as 87' fixed prices YTL.

EC(T) Electricity Consumption: EC is the amount of electricity consumed due to economical activities. It is measured as Gwh.

NEC(T) Non-Electricity Energy Consumption: NEC is the amount of non-electricity energy consumed due to economical activities. It is measured as Gwh.

TEC(T) Electricity Consumption in Transport Sector: TEC is the electricity consumed by transportation sector in present year. It is measured as Gwh.

HEC(T) Electricity Consumption in Household Sector: HEC is the electricity consumed by household sector in present year. It is measured as Gwh.

IEC(T) Electricity Consumption in Industrial Sector: IEC is the electricity consumed by industrial sector in present year. It is measured as Gwh.

TNEC(T) Non-Electricity Consumption in Transport Sector: TNEC is the non-electricity energy consumed by transportation sector in present year. It is measured as Gwh.

HNEC(T) Non-Electricity Consumption in Household Sector: HNEC is the non-electricity energy consumed by household sector in present year. It is measured as Gwh.

INEC(T) Non-Electricity Consumption in Industrial Sector: INEC is the non-electricity energy consumed by industrial sector in present year. It is measured as Gwh.

ITTE(T) Efficiency Index Transport Electricity: Efficiency index is the ratio of present years energy consumption per unit production to the base years energy consumption per unit production. For the base year this value is 100. Larger values than 100 means less efficient technologies are utilized and lower values mean more efficient technologies are developed and utilized. Each sector has two efficieny indexes for electricity and non-electricity energy demands.

ITTE is the efficiency index of transportation sector related to electricity demand. It has no units (ratio).

ITHE(T) Efficiency Index Household Electricity: ITHE is the efficiency index of household sector related to electricity demand. It has no units (ratio).

ITIE(T) Efficiency Index Household Electricity: ITIE is the efficiency index of industry sector related to electricity demand. It has no units (ratio).

ITTNE(T) Efficiency Index Household Electricity: ITTNE is the efficiency index of transport sector related to non-electricity energy demand. It has no units (ratio).

ITHNE(T) Efficiency Index Household Electricity: ITHNE is the efficiency index of household sector related to non-electricity energy demand. It has no units (ratio).

ITINE(T) Efficiency Index Household Electricity: ITINE is the efficiency index of industry sector related to non-electricity energy demand. It has no units (ratio).

AITTE(T) Average Efficiency Index Transport Electricity: Average Efficiency index is the weighted average of past years efficiency indexes and capacity expansions. For the base year this value is 100. Larger values than 100 means less efficient technologies are utilized and lower values mean more efficient technologies are developed and utilized. Each sector has two average efficiency indexes for electricity and non-electricity energy demands.

AITTE is the average efficiency index of transportation sector related to electricity demand. It has no units (ratio).

AITHE(T) Average Efficiency Index Household Electricity: AITHE is the average efficiency index of household sector related to electricity demand. It has no units (ratio).

AITIE(T) Average Efficiency Index Household Electricity: AITIE is the average efficiency index of industry sector related to electricity demand. It has no units (ratio).

AITTNE(T) Average Efficiency Index Household Electricity: AITTNE is the average efficiency index of transport sector related to non-electricity energy demand. It has no units (ratio).

AITHNE(T) Average Efficiency Index Household Electricity: AITHNE is the average efficiency index of household sector related to non-electricity energy demand. It has no units (ratio).

AITINE(T) Average Efficiency Index Household Electricity: AITINE is the average efficiency index of industry sector related to non-electricity energy demand. It has no units (ratio).

OEC(T) Oil Consumption due to Electricity Demand: OEC is the oil consumption due to electricity demand in present year. It is measured as Gwh.

CEC(T) Coal Consumption due to Electricity Demand: CEC is the coal consumption due to electricity demand in present year. It is measured as Gwh.

LEC(T) Lignite Consumption due to Electricity Demand: LEC is the lignite consumption due to electricity demand in present year. It is measured as Gwh.

GEC(T) Gas Consumption due to Electricity Demand: GEC is the gas consumption due to electricity demand in present year. It is measured as Gwh.

HYDEC(T) Hydro Consumption due to Electricity Demand: HYDEC is the hydro consumption due to electricity demand in present year. It is measured as Gwh.

GEOEC(T) Geothermal Consumption due to Electricity Demand: GEOEC is the geothermal consumption due to electricity demand in present year. It is measured as Gwh.

WEC(T) Wind Consumption due to Electricity Demand: WEC is the wind consumption due to electricity demand in present year. It is measured as Gwh.

SEC(T) Solar Consumption due to Electricity Demand: SEC is the solar consumption due to electricity demand in present year. It is measured as Gwh.

BIOEC(T) Bioenergy Consumption due to Electricity Demand: BIOEC is the bioenergy consumption due to electricity demand in present year. It is measured as Gwh.

OTEC(T) Other Energy Consumption due to Electricity Demand: OTEC is the other energy consumption due to electricity demand in present year. It is measured as Gwh.

ONEC(T) Oil Consumption due to Non-Electricity Energy Demand: OEC is the oil consumption due to non-electricity energy demand in present year. It is measured as Gwh.

CNEC(T) Coal Consumption due to Non-Electricity Energy Demand: CEC is the coal consumption due to non-electricity energy demand in present year. It is measured as Gwh.

LNEC(T) Lignite Consumption due to Non-Electricity Energy Demand: LEC is the lignite consumption due to non-electricity energy demand in present year. It is measured as Gwh.

GNEC(T) Gas Consumption due to Non-Electricity Energy Demand: GEC is the gas consumption due to non-electricity energy demand in present year. It is measured as Gwh.

GEONEC(T) Geothermal Consumption due to Non-Electricity Energy Demand: GEOEC is the geothermal consumption due to non-electricity energy demand in present year. It is measured as Gwh.

WNEC(T) Wind Consumption due to Non-Electricity Energy Demand: WEC is the wind consumption due to non-electricity energy demand in present year. It is measured as Gwh.

SNEC(T) Solar Consumption due to Non-Electricity Energy Demand: SEC is the solar consumption due to non-electricity energy demand in present year. It is measured as Gwh.

BIONEC(T) Bioenergy Consumption due to Non-Electricity Energy Demand: BIOEC is the bioenergy consumption due to non-electricity energy demand in present year. It is measured as Gwh.

OTNEC(T) Other Energy Consumption due to Non-Electricity Energy Demand: OTEC is the other energy consumption due to non-electricity energy demand in present year. It is measured as Gwh.

CO2EM(T) CO2 Emission: CO2EM is the CO2 emitted with the use of energy consumption due economical activity. IT is measured as tons.

ALPHA(T) Cost Of Efficiency Improvement Per Unit Capacity Per Unit Efficiency Index: It is the cost of improving one unit of capacity to decrease efficiency index for new capacity expansion. Its' unit is $/(Gwh*Efficiency index). Trough out the model it is calculated as to improve the efficiency of whole economy 30 % and expenditure of 7% of GDP is required (Laitner, 2000)

5. MODEL CALIBRATION

5.1. Base Year Model Assumptions

All energy units are represented as Gwh. All prices of model are in YTL form and based on year 1987. They also are kept constant for time window. The model is calibrated for a reference scenario with year 2000 being the base year (there were no extra ordinary political, social or economic events that could affect energy consumption habits or economic balances in year 2000) and solved in one year time steps. Results for the first period are compared with actual realizations, verifying the behavior pattern. Economic variables (e.g. GDP, export, import, etc), and energy composition between 2000 and 2005 are compared with the actual dynamics. Pattern similarities are recognized.

Base year data and main assumptions of the model are given in Table 1, 2 and 3, respectively.

Table 1 Macroeconomic Data

Macroeconomic Data	**Value (10^3 YTL)** *(in 1987 real prices)*
GDP	846.504 (1)
Consumption	31.320 (2)
Import	123.543 (2)
Export	242.430 (2)
Investment	934.071
Workers' Remittances	20.283 (1)
Tourism Revenues	33.965 (1)
Other Incomes from Abroad	65.005 (1)

Data Sources: (1) SPO, 2005; (2) TSI, 2005.

Table 2 Energy Data for the Base Year (2000)

	Electric Energy (Gwh)	**Non-electric Energy (Ktoe)**
Final Energy Consumption	95873.00 (1)	541922.00 (1)
Sectoral		
Transport	765.00 (1)	141144.00 (1)
Household&Service	49019.00 (1)	209263.00 (1)
Industry	46089.00 (1)	191515.00 (1)
Source		
Petroleum products	7140.85 (1)	159525.36 (1)
Hard coal	2272.22 (1)	115053.41 (1)
Lignite and peat	26240.6 (1)	174669.99 (1)
Natural Gas	35450.07 (1)	39603.68 (1)
Derived Gases	657.72 (1)	-
Hydro	23900.49 (1)	-
Goethermal	58.33 (1)	4607.27 (1)

Wind	25.33 (1)	0.00 (1)
Solar	-	0.00 (1)
Biomass	127.39 (1)	0.00 (1)
Wood	-	48130.31 (1)
Industrial Wastes	-	332.19 (1)

Data Sources: (1) EUROSTAT, 2007

Table 3 BAU Assumptions

Macroeconomic Assumptions:	
Marginal Productivity of Capital	15%
Labor Force Growth Rate	1.0% per year
Upper Limit on Investment	15% of Previous Year
Upper Limit on Imports	25% of Previous Year
Upper Limit on Exports	15% of Previous Year
Upper Limit on Workers Remittances	25% of Previous Year
Upper Limit on Turism Revenues	25% of Previous Year
Value Share of Capital* *(sk)*	40.0%
Value Share of Labor* *(sl)*	60.0%
Value Share of Electricity Consumption in Transport** *(ste)*	0.7%
Value Share of Electricity Consumption in Household&Service** *(she)*	52.8%
Value Share of Electricity Consumption in Industry** *(sie)*	46.5%
Value Share of Non-Electricity Consumption in Transport*** *(stne)*	54.0%
Value Share of Non-Electricity Consumption in Household&Service*** *(shne)*	21.0%
Value Share of non-Electricity Consumption in Industry** *(sine)*	25.0%
Elasticity of Substitution****	0.3
Capital/Output Ratio	3.0
Production function parameters:	
a: 1.80208e-12; b: 9.508898e-8; c: 1.621033e-7	

* in capital-labor pair; ** in electricity demand; *** in non-electricity demand; ****between energy pairs and primary factors

5.2. Base Case Scenario Results

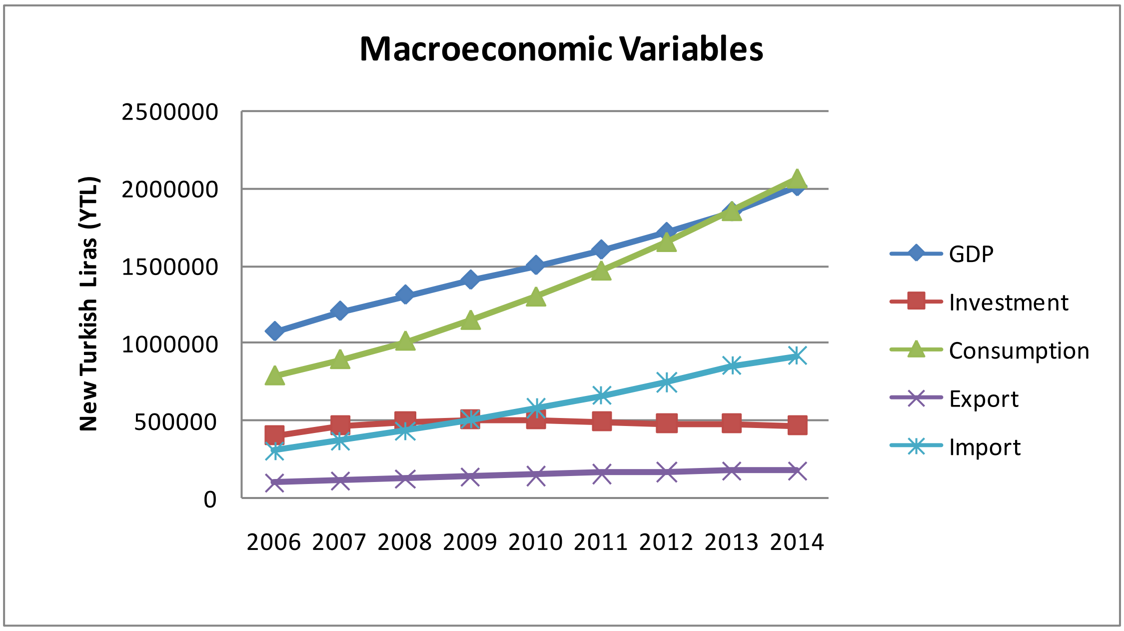


Figure 1 Macroeconomic Variables of Base Case Scenario

As can be seen from Figure 1 GDP continuously grows over the time horizon with a 8% average growth rate. Consumption also increases over the time horizon but a higher average growth rate (13%) and reaches GDP at the end of time horizon. Another interesting point is the relation between import and export. Even though export grows with an average growth rate of 7%, import extends the gap since its growth rate is almost double of export. Investment rises at the beginning of the period and then stabilizes around 0.5 Milllion YTL.

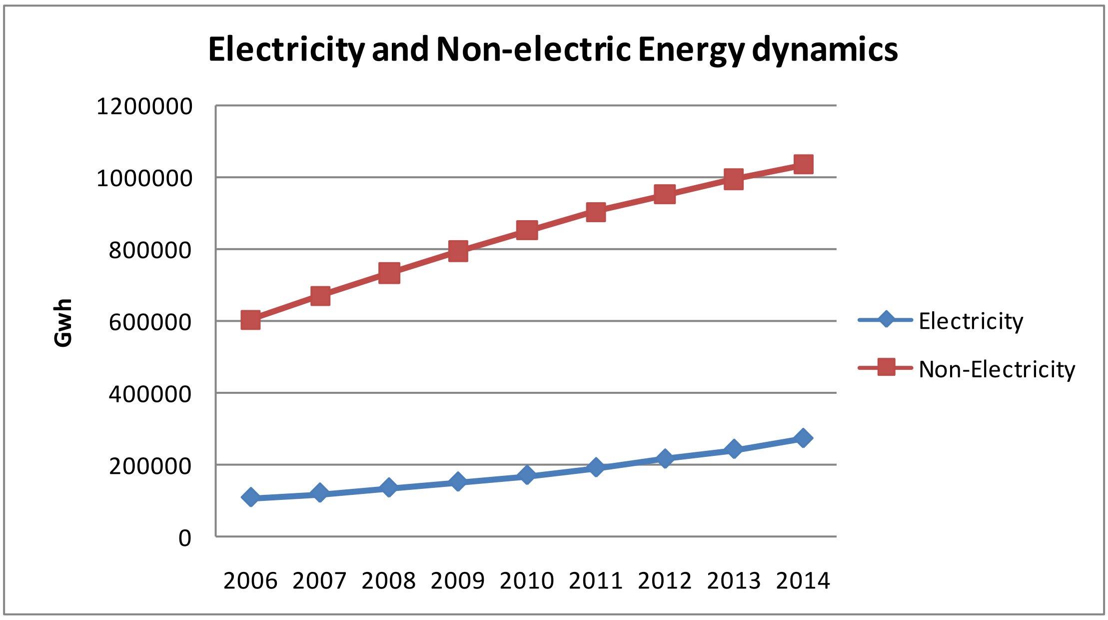


Figure 2 Total Electricity and Non-Electric Energy Dynamics

Figure 2 shows that both energy types grow but the patterns are different. Non-electricity rises with a decreasing growth rate while electricity increases with a smaller but increasing growth rate.

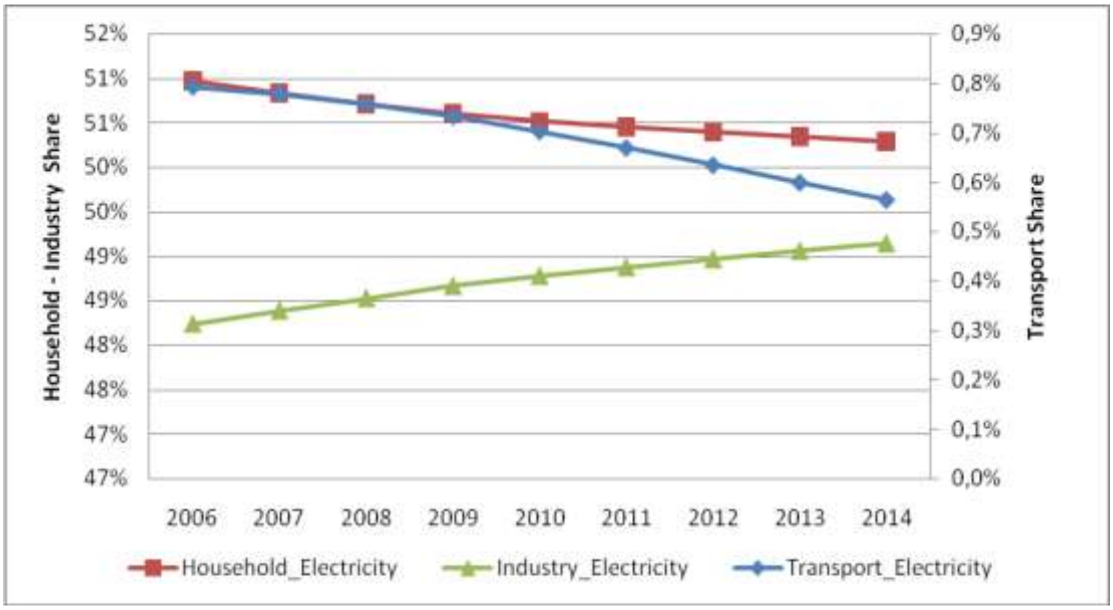


Figure 3 Share of Sectors in Electricity Consumption

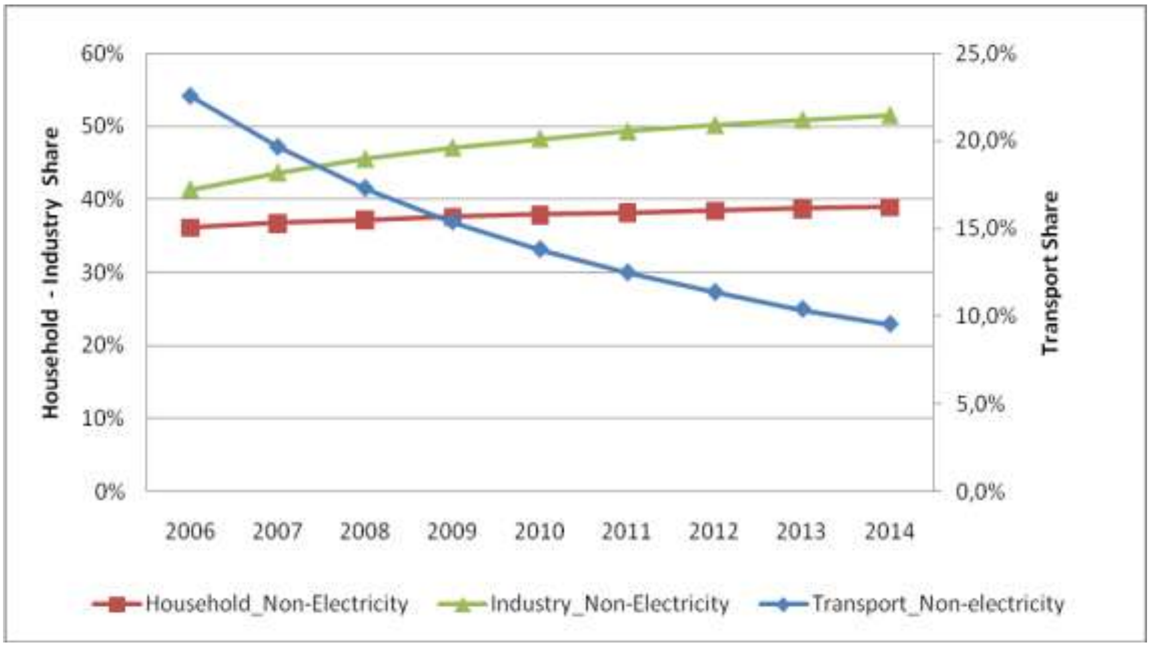


Figure 4 Share of Sectors in Non-Electricity Consumption

Figure 3 and 4 reflects the sectoral composition of electricity and non-electricity consumptions. In electricity consumption, all sectors increase in physical values. However, since the electricity consumption in transport is almost stable over the time horizon, its share declines due to other significant growths of two sectors. Non-electricity consumption has a similar behavior. Non-electric energy consumption in transport grows with very small rates when physical values are evaluated. However, its share declines due to fast increase of other two sectors.

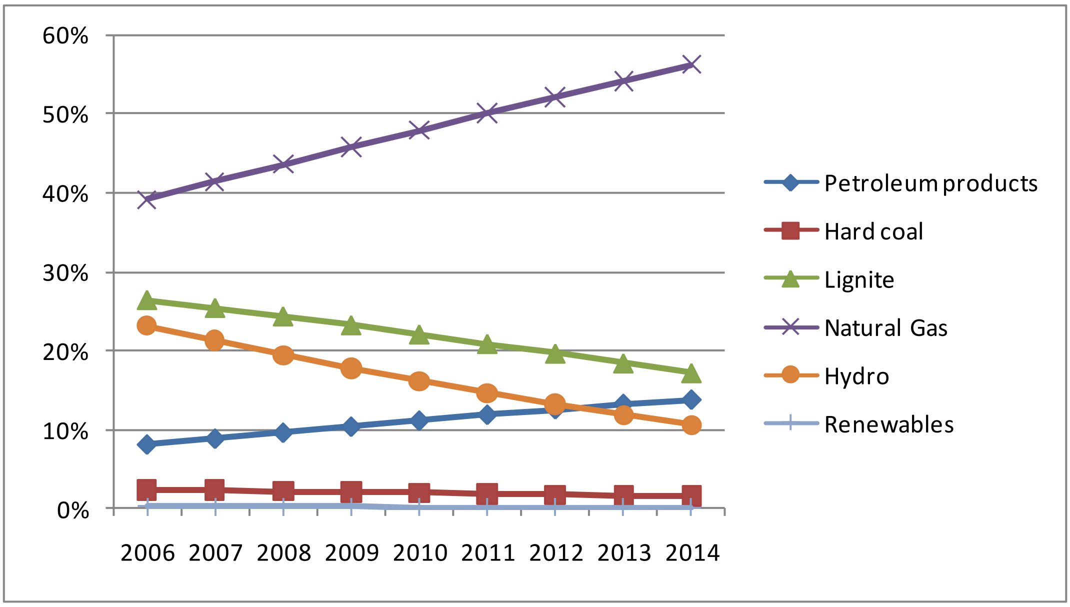


Figure 5 Share of Resources in Electricity Consumption

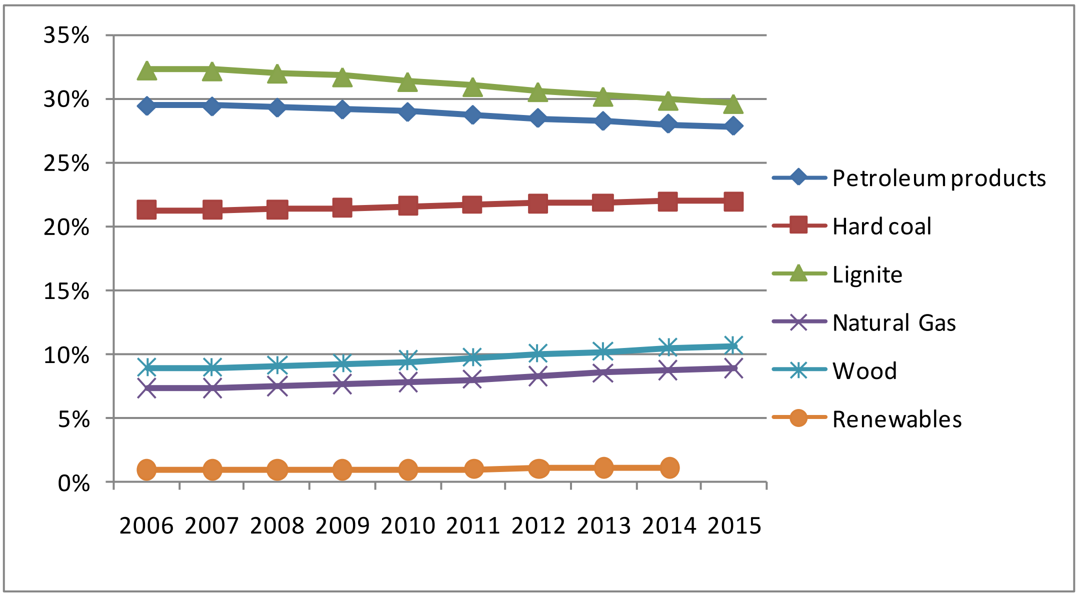


Figure 6 Share of Resources in Non-Electricity Consumption

The resource based share of electricity and non-electricity are illustrated in Figure 5 and 6. When Figure 5 is analyzed, the dominancy of natural gas in electricity consumption is realized. This is in line with the current situation of Turkey. Hydro electricity and lignite show similar behavior pattern. Although their physical values increases, their shares decline due to gradually growth in natural gas consumption in electricity production. Petroleum products share in electricity production grows with a declining rate and almost stabilizes at the end of the period. Hard coal consumption share is stable over the time horizon. Both petroleum and hard coal consumption are in line with the past historical data. Renewable share (excluding hydro) is insignificant. This is why they cannot be observed in Figure 5. However, while they are analyzed within themselves, a declining trend of their share is found. Figure 6 shows the non-electricity resource consumption patterns. It is clearly seen that hard coal has a stable share pattern over time horizon. Besides declines in petroleum products and lignite are compensated by raises in natural gas and wood shares. Renewable (significantly geothermal) share is around 1% and a closer look shows that there is a small but steady growth.

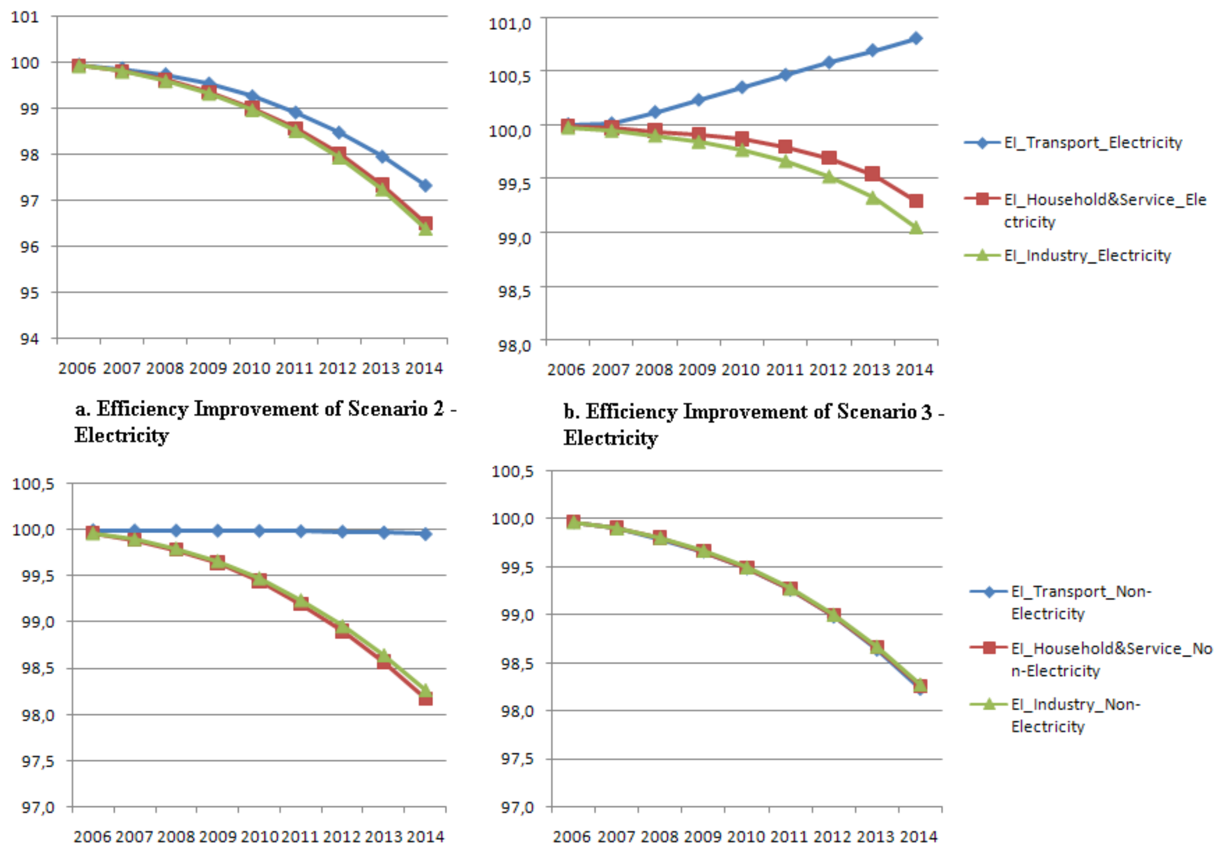
CO2 emissions are also investigated. There is a 9% average growth of emissions over the time horizon.

6. SCENARIO ANALYSIS

In addition to the base case scenario, two other scenarios including efficiency improvement and CO2 emission restriction are defined as shown in Table 3.

Table 4 Scenario Definitions

Scenario	**Description**
Base Case	*Business-As-Usual*
Scenario2	Base Case + Efficiency Improvement
Scenario3	Scenario2 + CO2 Emission Restriction



a. Efficiency Improvement of Scenario 2 - Electricity

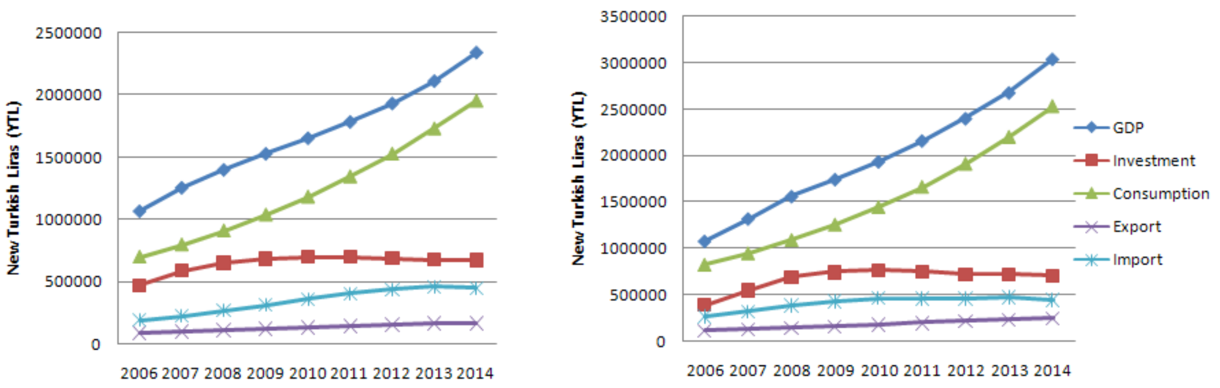
b. Efficiency Improvement of Scenario 3 - Electricity

c. Efficiency Improvement in Scenario 2 - Non-electricity

d. Efficiency Improvement in Scenario 3- Non-electricity

Figure 7 Average Efficiency Improvement in Electricity and Non-electricity Energy

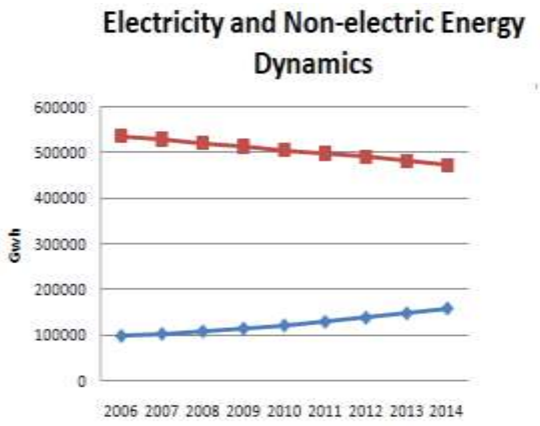
Scenario 2 leads to improvement in electricity efficiencies (see also Figure 7.a) in all three sectors in which transport has the lowest while in non-electricity efficiencies transport has no improvement. Improvements in efficiency decrease in Scenario 3 due to dramatic decline newly added capacities. Furthermore, transport shows a worse efficiency value compared to other scenarios.



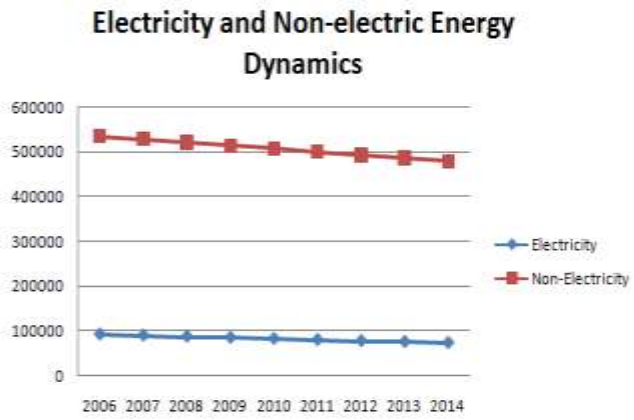
a. Macroeconomic Results of Scenario 2

b. Macroeconomic Results of Scenario 3

When Scenario 2 is compared with base case scenarios, it is observed that efficiency improvement leads to significant growth in GDP and consumption. This is mainly due to decreases in total energy consumption cost. Furthermore, investment stabilizes at higher levels and also there is significant fall in import values. It is clearly observed that there are some improvements in economic variables with lower efficiency index (more improved). In scenario 3, in which emission restriction is applied, GDP and consumption reach higher values compared to Scenario 2. As shown below figures, this is due to the main reason, shrinkage in energy demand.

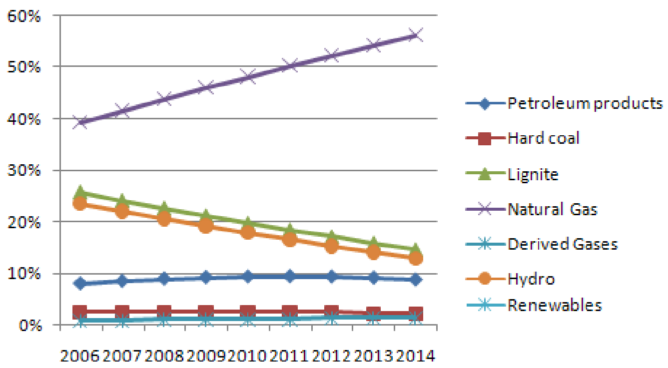


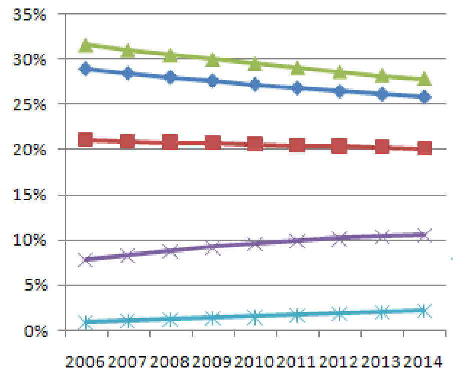
a. Energy Demand Dynamics of Scenario 2



b. Energy Demand Dynamics of Scenario 3

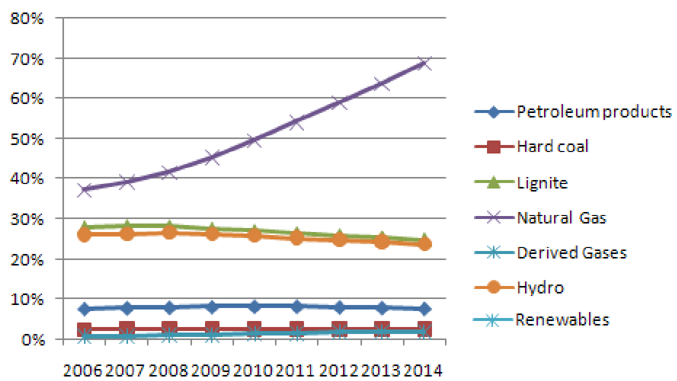
Scenario 2 results in declines in both electricity (with the same pattern) and non-electricity energy (with a declining pattern). When CO2 emission restriction is applied in Scenario 3, these decline trends become more acute.

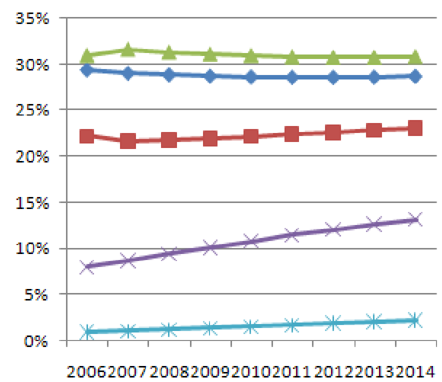




a. Share of Resources in Electricity Consumption of Scenario 2

b. Share of Resources in Non-Electricity Consumption of Scenario 2





c. Share of Resources in Electricity Consumption of Scenario 3

d. Share of Resources in Non-Electricity Consumption of Scenario 3

CO2 Emission Scenarios leads to higher hydro-electricity (mainly in electricity part) and natural gas (mainly in electricity and non-electricity parts) shares as expected. The effects of Scenario 3 on resources are limited in non-electricity energy demand.

7. CONCLUSION

This study analyzes an integrated energy-economy-environment model to explore the transition and integration opportunities of energy efficient technologies on different energy technologies in Turkey. Giving attention to the economical and energy-emission policy aspects, the relationships among the main energy demanding sectors, investments on new and energy efficient technologies, financial burden, and CO_2 emissions are investigated. The model takes efficiency improvement into consideration. The aim is to decrease energy consumption cost and improve economic variables by satisfying the same demand with more efficient/less energy consumed technologies. Efficiency is improved until the marginal cost of efficiency improvement equals to the marginal cost of energy consumption of model. In addition to a Base Case Scenario, two other scenarios including efficiency improvement and CO2 emission restriction are defined.

The model results show that both Scenario 2 and Scenario 3 support efficiency improvement, except Scenario 2 in electricity consumed technologies of transport sector which is sensible since electricity consumed technologies are slowly abandoned. In both scenarios, efficiency improvement encourages the economic variables (especially GDP and consumption) and depresses energy consumption figures. Due to the more intense shrinkage in energy demand of Scenario 3, the increase amounts of economic variables are more accurate.

As a further research, the ways of possible improvements in model structure for more complex scenario applications can be investigated. Moreover, to get an insight about the interactions and linkage among the energy prices and efficiency improvement a redesigned version of the existing model can be constructed and analyzed. Sectoral efficiency improvement scenarios and also different CO2 emission payment mechanisms can be applied.

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