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Abstract

We present Turkey's manufacturing-sector innovation data and, for the first time, analyze likely relationships among GDP growth, sectoral innovation intensities, energy consumptions, and energy-saving potentials. We detect a power-law-like relationship between the projected energy-saving potentials and realized energy consumptions of the manufacturing-sector groups. We observe that the energy consumptions of the sectors do not change significantly despite varying innovation levels during transitions from economic crisis and recovery periods. We conclude that the Turkey's manufacturing sectors' energy consumptions are insensitive to their innovation levels, or their innovation activities are not energy-efficiency- and energy-saving-oriented, reflecting Turkey's past supply-oriented energy policy. The leader innovating sectors are, nevertheless, expected to contribute more to Turkey's energy-saving and energy-efficiency policies if their innovation potentials can be directed to achieve higher energy savings and energy efficiencies via government incentives within the agenda of the recent energy-efficiency and R&D laws.

Keywords: Manufacturing sector; Innovation; Energy consumption; Energy saving potential; Energy efficiency; R&D; GDP; Turkey

1. Motivation

Literature reveals that energy-saving (ES), energy-efficiency (EE) and greenhouse-gas emissions may be related to innovation and R&D activity levels. Turkey's manufacturing technology is not very energy-efficient and current R&D and innovation activities are not very much concerned with ES and EE, reflecting Turkey's past supply-oriented energy policy. However, recent laws on EE and R&D aim to revert this policy towards ES and EE. Turkey's law about the support of R&D activities (RDL in short) supports generation of technological know-how to make the economy internationally competitive through R&D and innovation. RDL exploits innovations in developing technology-intensive products and production processes, improving efficiency and costs, and commercializing technological know-how.

We expect that, in the medium to long run, supports and incentives of RDL will espouse implementation of Turkey's ES, EE, and emission-reduction policies. In support of our such views, we present Turkey's manufacturing-sector innovation data and analyze the relationships among sectoral innovations, energy consumptions, and ES potentials. Consequently, we infer the sectors that are expected to contribute more to Turkey's energy/emission policies, and identify the sectors to be supported and closely-monitored by the government. Turkish government must support and develop a shared vision of energy-related R&D and innovation among industry, universities, government-based R&D centers, and budding energy-service-company (ESCO) market.

Due to poor data-collection practice in Turkey in the past, the data sets we used, in particular the ES-potential data, are not very adequate. However, the results are coherent enough to reveal the policy directions. This work should also encourage more diverse and detailed collection of energy- and innovation-related data from the Turkish manufacturing sector to deduce more strong and sound policy suggestions in the future.

The organization of this paper is as follows: Section 2 reviews literature on energy-innovation relationships in the world and Turkey. Section 3 summarizes the energy profile of Turkey. Section 4 gives the sources and description of our data, and the definition of term "innovation" as used in this work. In Section 5, we present and analyze Turkey's industrial-sector innovation data in conjunction with GDP, sectoral energy consumptions and ES potentials. Finally, Section 6 presents our views and policy suggestions.

2. Innovation and energy efficiency

Oikonomou et al. (2009) state that EE is used with different meanings in public policy making and distinguish EE and energy conservation with respect to the fact that EE refers to "adoption of a specific (new) technology" that reduces overall energy consumption without changing consumers' energy-consumption behavior. The authors verify that changing behavior from one side and technology (or, innovation in broad sense) from the other are the key issues for public energy policy.

Literature on innovation is vast, yet that on innovation-energy relationships is relatively scarce. Elliott and Pye (1998) review US industrial energy use and intensity in relation to innovations in US industrial sector and conclude that policies promoting innovation and investment in process equipment are most likely to lead to greater industrial EE and reduced carbon emissions. Sagar and Holdren (2002) discuss that energy-price trends reshape both the willingness and the capacity of the energy sector to innovate, and that the energy-related R&D is an essential in examining the innovative capacity of the energy sector. Foxon et al. (2005) analyze innovation systems in the UK for new and renewable energy technologies, and suggest policies for improving the effectiveness of innovation systems. Hekkert et al. (2007) apply the innovation systems theory in explaining the successful diffusion of cogeneration technology in the Netherlands. The authors show that a well functioning technological innovation system and actions of the government explain the successful technology diffusion. Beerepoot and Beerepoot (2007) focus on the role of strict government regulation as an incentive to incremental ES innovations in the Dutch residential-building sector and conclude that project-based energy performance policy does not contribute to the diffusion of radical innovation in energy techniques for residential buildings. Kemfert and Truong (2007) model the economic impacts of emissions stabilization scenarios with and without "induced technological change" (ITC). ITC is a hypothesis which sees R&D investments as profit-motivated and price-change stimulated. The authors discuss that climate-policy measures that increase fuel prices augment the market for low-carbon technologies, which in turn creates incentives for increased R&D expenditures; leading to technological changes that lower the costs of low-carbon technologies. The authors conclude that improved technological innovations are triggered by increased R&D expenditures that advance EEs and reduce compliance costs. Without the ITC effect, emissions targets are primarily reached by declines in production, resulting in overall welfare reductions. With the ITC effect, emissions mitigation can result in fewer production and GDP drawbacks. The authors also point out that without the inclusion of ITC, countries react basically with declines in production rather than increases in R&D expenditures. Very recently, Popp et al. (2009) prepared an excellent review scrutinizing the role of technological change on environmental economics for the forthcoming Handbook of Economics of Technical Change. In this review, some significant works cited in conjunction with the relationships among innovation (technological change), EE, and ES are Mountain et al. (1989), Sterner (1990), Berndt et al. (1993), Newell et al. (1999), Popp (2001), Nijkamp et al. (2001), Popp (2002), Mulder et al. (2003), Anderson and Newell (2004), Linn (2008), and Sue Wing (2008). Some of the conclusions of these works are *i)* the technology is energy saving; *ii)* energy patents leads to long-run energy savings; *iii)* science and technology (S&T) takeoff should have an energy-saving bias resulting in lower energy prices, however, this leads to more economic growth and greater energy consumption by households, so that the net effect of the S&T takeoff is greater energy use and more emissions; *iv)* increase in the price of energy leads to technology adoption that negligibly reduces energy demand; *v)* energy prices and regulatory standards affect EE-related innovation; and *vi)* economic barriers affect adoption of EE technology more than financial and uncertainty barriers.

Extensive coverage of Turkey's innovation profile and policy suggestions were given by Elci (2003). Uzun (2001) studied the technological innovation activities in Turkish manufacturing industry and concluded that activities were more widespread in the firms with large number of employees and in-house R&D was the main source of innovation. The author reported that 51% of the firms carried out joint R&D with consultancy firms and 52% of the firms with which Turkish firms cooperate were in EU countries. It was also found that in the majority of the manufacturing sectors, more than 50% of total sales were derived from technologically new and improved products, and only 19% of the firms had patent applications with very few patented inventions. However, analysis of innovation activities showed that sales of new products, R&D expenditures, and firm sizes correlated only weakly. Karaoz and Albeni (2005) developed a model based on production function to estimate the technological learning levels for 28 Turkish manufacturing industries. The results show that the technological learning in Turkish manufacturing industries varies over time and each industry follows a distinct learning path. Soytas and Sari (2007) investigated the relationship between energy and production at the industry level in Turkey. They observed that there was a unidirectional causality running from electricity consumption to value added, and thus, energy input was closely related to production. The authors conclude that ES technologies and increased EE may increase the growth in manufacturing value added since manufacturing output, labor, fixed investment, and electricity consumption move together in the long-run.

3. Turkey's energy profile

As stated in International Energy Agency's (IEA) 2005 review of Turkey, Turkey's energy policy had been highly supply-oriented, with emphasis placed on ensuring additional supply to meet the growing demand, while EE had been a lower priority. Legislative framework has been upgraded to be compatible with that of the EU countries since 2001. Lately, new legal frameworks, such as the Electricity Market Law, Natural Gas Market Law, Petroleum Market Law, and Energy-Efficiency Law have been put into effect to end the state monopoly and allow private-sector participation in energy industries, aiming at cost-effective pricing through competition under independent regulation and supervision of the Energy Market Regulatory Authority (EMRA, www.epdk.org.tr). These developments are mostly due to ongoing harmonization process of the Turkish legislation with the EU.

Turkey's energy demand has been growing with a rate of 6% for decades and this demand is expected to persist as a result of rapid urbanization and industrialization. The distribution of energy consumption is as follows: industry 36%, heating (households) 35%, transportation 20%, and other areas 9%. The leading energy consumers of the industrial sectors are the iron and steel sector, chemicals and petrochemicals, and textile and leather industries. The energy use of the transport sector has grown significantly in the last decade and is expected to grow further. Primary energy demand has been projected to reach 220 million TOE (tone of oil equivalent, TOE = 42×10^9 J) in 2020; a 150% increase compared to the current level. The limited availability and production capacity of domestic energy sources cause import dependency, primarily on oil and gas. At present, about 30% of the total energy demand is met by domestic resources. In 2006, about 74% of the energy demand of Turkey has been satisfied by imports, with a cost of $28 billion, rendering current-account-deficit problem a major issue.

Hepbasli and Ozalp (2003) investigated the development of industrial EE and management studies in Turkey and concluded that the Turkish industrial sector had an ES potential of 30%. The authors also noted that by means of regulations on industrial EE and announcements related to designing energy management courses and performing energy audits, the Turkish industrial sector had significantly accelerated efforts in implementing EE and energy management studies. Sari and Soytas (2004) investigated the energy consumption and economic growth relationship for Turkey by examining how much of the variance in GDP growth can be explained by the growth of different sources of energy consumption and employment. The authors conclude that energy consumption explains a significant portion of forecast error variance of GDP, and energy consumption is almost as important as employment in Turkey. Utlu and Hepbasli (2004) and Hepbasli and Utlu (2004) analyzed sectoral energy utilization in Turkey from 1990 to 2000. Turkey's overall first-law efficiencies for the utility, industrial, residential-commercial, and transportation sectors were found to be 31.8, 63.6, 56.2, and 21.7%, respectively. Total energy utilization efficiency was calculated as 44.7%. Ediger and Huvaz (2006) investigated the sectoral energy use in the Turkish economy when significant changes occurred in the economic and demographic structure of the country, and concluded that a close relationship existed between primary energy consumption and GDP, with significant variations in the sectoral energy use that were related to the economic policies of the governments. Soytas and Sari (2009) investigated the long run Granger causality relationship between economic growth, CO_2 emissions, and energy consumption in Turkey. They observed that CO_2 emissions Granger-caused energy consumption, but the reverse was not true. The authors conclude that, due to the lack of a long-run causal link between income and emissions, to reduce carbon emissions, Turkey does not have to give up economic growth.

Fig.1 shows the historical (1970-2006) and forecasted (2007-2020) energy consumptions in Turkey's major sectors. The data and the forecasted values were obtained from the Ministry of Energy and Natural Resources (MENR, www.enerji.gov.tr). The forecasts

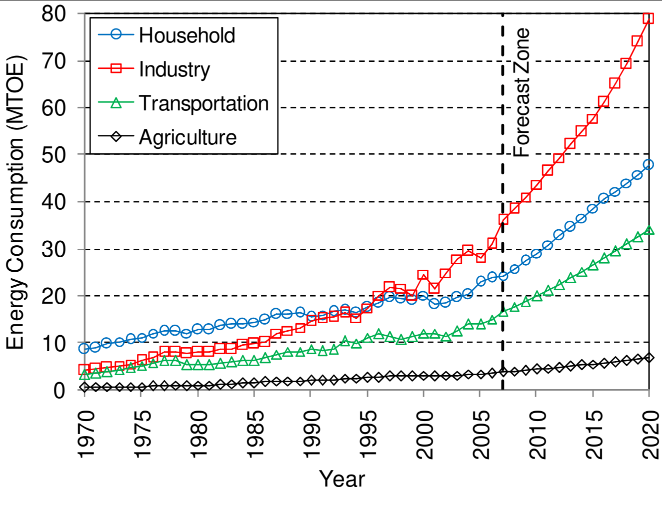

Fig. 1. Historical (1970-2006) and forecasted (2007-2020) energy consumptions in Turkey's sectors (MENR, www.enerji.gov.tr).

have been done before the global economic crisis of 2008-2009 that began in July 2007 as a financial crisis. Turkey as well has been affected very badly by this crisis such that the growths in the manufacturing, transportation, and agricultural sectors in the 1st quarter of 2009 have just been disclosed as −18.5, −17.6, and −3.0%, respectively. The GDP growth rate in the same period has been reported as −13.8%; a record plunge after the 1945 (World War II) value of −15.3%. Therefore, the 2008-2012 forecasts of the MENR are very questionable. However, global economists foresee that the effects of the crisis will diminish around 2012 and especially the developing countries like Turkey will live a very fast recovery period. Thus, the authors of this paper expect that Turkey can easily reach the energy consumption levels forecasted by the MENR for the years 2015-2020. Therefore, the manufacturing sector will be the dominating sector in the energy consumption (and CO_2 emissions (Tunc et al., 2009)) of Turkey in the near future as well.

4. Data and description

Sectoral innovation data (technological innovation statistics) used in this work were obtained from the Turkish Statistical Institute (TSI) (www.turkstat.gov.tr). TSI compiles data through surveys in compliance with the international standard methodology for innovation statistics entitled "Oslo Manual" (www.oecd.org) (also known as the "The Measurement of Scientific and Technological Activities, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data") which defines the "innovation" and gives methodological guidelines for collecting and using data on industrial innovation. The latest 3rd edition (dates back to 2005) of the "Oslo Manual" is a 163-page document and can be downloaded from OECD web site. The TSI survey is designed to obtain information on innovation activities within enterprises, as well as various aspects of the process such as the effects of innovation, sources of information used, costs etc. The classification of establishments by type of activity is determined in accordance with the Statistical Classification of Economic Activities in the European Community (NACE Rev.1.1). There are no important differences between Turkey's methodology and relevant international or regional standards. The data (taken directly from enterprises and collected by the methods of face to face) are based upon the use of innovation within the enterprises, innovation expenditures, innovative enterprises cooperating, venture capital, share of public funding for innovation, education affect on innovation, technology expenditures, patents, trademarks etc. Enterprise is defined as an organizational form that produces goods and services at one or more locations using decision autonomy at first degree.

According to the TSI innovation manuals, the term "innovation" covers product, process, organizational, and marketing innovations. A *product innovation* is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses and includes significant improvements in technical specifications, components and materials, or other functional characteristics. Product innovations can utilize new knowledge or technologies, or can be based on new uses or combinations of existing knowledge or technologies. Design is an integral part of the development and implementation of product innovations. A *process innovation* is the implementation of a new or significantly improved production or delivery method and includes significant changes in techniques, equipment and/or software. Process innovations can be intended to decrease unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products. An *organizational innovation* is the implementation of a new organizational method in the firm's business practices, workplace organization or external relations. Organizational innovations can be intended to increase a firm's performance by reducing administrative costs or transaction costs, improving workplace satisfaction (and thus labor productivity), gaining access to nontradable assets (such as non-codified external knowledge) or reducing costs of supplies. A *marketing innovation* is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. Marketing innovations are aimed at better addressing customer needs, opening up new markets, or newly positioning a firm's product on the market, with the objective of increasing the firm's sales.

As can be understood from these definitions, the standard international description of innovation is very broad. Implementation of innovations may result in decrease or increase in energy consumptions. To the knowledge of the authors, what portion of innovation activities yields favorable results, directly or indirectly, in terms of EE and ES is unknown. We have no information that any standard innovation survey conducted in the world aims to assess the presence of EE or ES oriented innovation activities in the enterprises.

The TSI publishes Turkey's sectoral innovation data as "the percentage of enterprises innovating in each sector", without disclosing the number and nature of enterprises surveyed, and without distinguishing whether the innovations are product, process, organizational, or marketing innovations. However, innovation is a consequence of knowledge accumulation and R&D experience, which also expedite compliance with laws and regulations. Thus, it should be logical to think that enterprises accustomed to R&D and innovation activities should obey and implement any EE and ES measures with less resistance and high effectiveness, leading to more successful completion of energy projects with more efficient utilization of limited funds.

We used the innovation data disclosed by the TSI in 22 sector detail as an indication of "innovation intensity" of the manufacturing sectors. This data set is given in Table 1.

The energy consumptions of the same 22 manufacturing sectors (for which the innovation data are present) have been disclosed by the TSI relatively recently in 2008 (as a new standard), but only for the year 2005. This data set is also given in Table 1. The TSI, in the past, published the energy consumptions of the group of manufacturing sectors (as the old standard) for the years 1999, 2000, and 2001 only. The old-standard data set is in 8 sector-group detail. Since these 8 sector groups comprise the 22 sectors for which there are innovation and 2005 energy-consumption data, we, via averaging, grouped the 22 manufacturing sectors MS1 through MS22 given in Table 1 as sector groups S1 through S8, as given in Table 2. This 8-group-averaged energy-consumption data set is given in Table 3.

As a proxy of aggregate economic activity we used the real GDP values (1987 fixed prices) published also by the TSI.

For the Turkey's energy-saving-potentials, there is a single data source which sectorwise is not as detailed as the innovation and 2005 energy-consumption data. Kavak (2005) investigated the EE and ES potentials of several energy-intensive sectors in the Turkish industry as a thesis-work requirement for planning expertise in the State Planning Organization (DPT, www.dpt.gov.tr) in collaboration with the experts from the EIE (General Directorate of Electrical Power Resources Survey and Development Administration) (www.eie.gov.tr). This valuable work is the only source of projected ES-potential data for the Turkish manufacturing sectors. The lack of detailed ES-potential data for Turkey has been critically mentioned by other researchers as well (Bosseboeuf and Lapillonne, 2006). Kavak's data set corresponds to 8-group-detailed energy-consumption data published by the TSI for the years 1999-2000-2001, and therefore, Kavak's data set is also given in Table 3.

5. Analyses of innovation and energy data

Innovation and energy consumption data for the Turkish manufacturing sectors are given in Table 1. The NACE codes (pan-European system which groups organizations according to activities) of the sectors are also provided. The innovation data (% innovative) represent the percentages of the enterprises innovating in each sector, as published by the TSI. Computed values of the sectorwise and periodwise average innovations, and average growth rates of GDP and average industrial energy consumption are also included in Table 1. For the ease of referencing throughout this work, the manufacturing sectors are coded as MS1-MS22.

TABLE 1 ABOUT HERE

As the average GDP as well as the average industrial energy-consumption growth rates (last two rows of Table 1) indicate, the 1995-1997 period is an economic boom period, 1998-2000 is a recession period, and 2002-2004 period involves the vestige of the

2001 economic crisis of Turkey followed by a fast recovery phase. The average innovations in the manufacturing sector (the third row from the last row) follow the GDP growth, though weakly. If examined sectorwise, MS-3, 5, 7 through 13, 18, 20, and 22, mostly which are also highly energy intensive sectors, are positively correlated with the growth rates of the GDP and average industrial energy-consumption. Sectors MS-1, 2, 17, and 21, which are not energy intensive, are negatively correlated with GDP growth. Sectors MS-7, 9, 18, 20, and 22 have more increases in innovation than the GDP growth when the 1998-2000 values are compared with the 2002-2004 recovery-period values. Sectors MS-4, 6, 14, and 15 show increasing innovation path regardless of the growth-rate declines in the GDP and in the average industrial energy-consumption. In general, it can be concluded that, with respect to innovation activities, the high-energy-consuming manufacturing sectors of Turkey are more susceptible to aggregate economic activity (as measured by the GDP) compared to the sectors that use less energy.

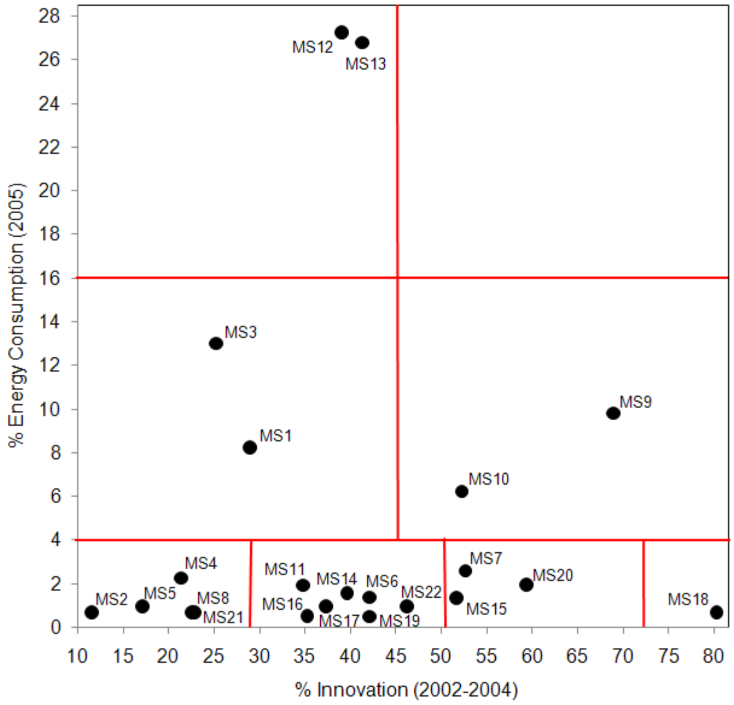

Fig. 2. Innovation and energy-consumption in Turkish manufacturing sectors.

Fig. 2 shows the clustering of the individual Turkish manufacturing sectors (MS1 through MS22) on the energy-consumption versus innovation plane. The vertical and horizontal lines were drawn rather subjectively. With respect to energy consumption, most of the sectors cluster below the 4% level. These low-energy-consuming sectors form four clusters with respect to their innovation values. Although, their individual energy consumptions are low, there are 16 sectors in this zone, and their contributions to the total energy consumption of the Turkish manufacturing sector add up to 11.6% (computed from Table 1 values). Sectors MS-1, 3, 9, and 10 form the medium-level energy-consumption zone, bounded roughly between 4 to 16% levels, and these four sectors' contribution to the total energy consumption of the Turkish manufacturing sector is 35.3%. In this zone, sectors MS1 and MS3 form the relatively-low-innovators cluster with 20.2% contribution to the total energy consumption, and sectors MS9 and MS10 form the relatively-high-innovators cluster with 15.1% contribution to the total energy consumption. The two very-high-energy-consuming sectors, MS12 and MS13, have medium innovations and their contributions to the total energy consumption of the Turkish manufacturing sector is 53.1%.

At this point, without considering the information on energy-saving potentials of the sectors, we can make the following policy suggestions based on Fig. 2. Primarily, the medium innovation activities of the sectors MS12 and MS13 should be enhanced and incited towards increasing EE and ES in these sectors via government incentives during the implementation of the EE and R&D laws. Since these two sectors alone consume 53.1% of the total energy in the Turkish manufacturing sector, even the small improvements as a result of EE- and ES-related innovations should yield appreciable gains. Subsequently, the attention and the incentives should be allocated to sectors MS3 and MS1 with the same objective. These four sectors (MS-12, 13, 3, and 1) deserve special attention since their contribution to the total energy in the Turkish manufacturing sector amounts to 73.3%.

Turkey's ES-potential data are not sectorwise detailed as the innovation data given as in Table 1. Kavak (2005) investigated EE and ES potentials of several energy-intensive sectors in the Turkish industry. Kavak's data with respect to projected ES potentials for these groups of industrial sectors (Table 2) are given in the second column of Table 3. Since the sectors S1 through S8 in Table 2 comprise sectors MS1 through MS22 of Table 1, we grouped the manufacturing sectors of Table 1 as sectors S1 through S8, as shown in Table 2. Innovation values in Table 1 averaged over these grouped sectors are given in Table 2. Energy-consumption values and their percentages for these grouped sectors are also given in Table 3.

TABLE 2 ABOUT HERE

TABLE 3 ABOUT HERE

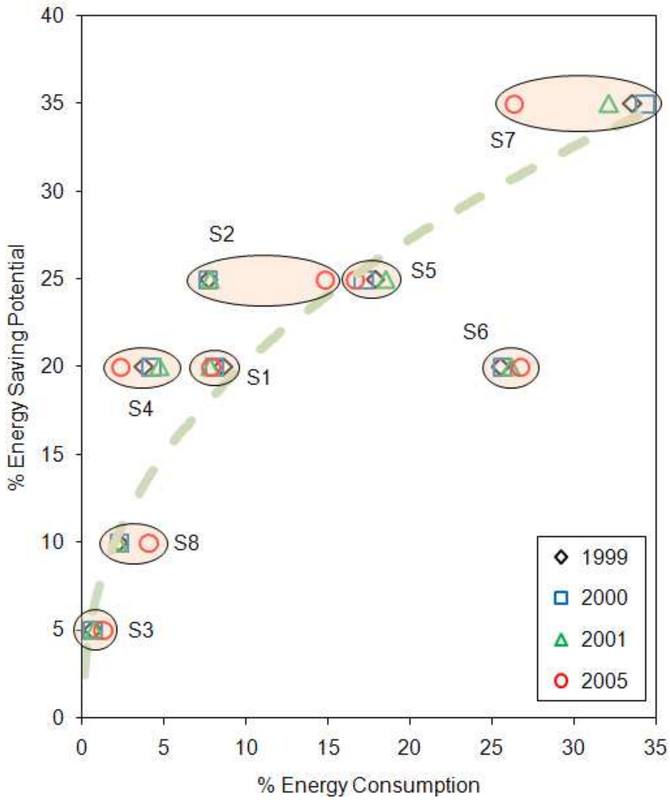

Fig. 3. Historical energy-consumption and energy-saving-potential in Turkish manufacturing sector groups.

Fig. 3 shows the ES potentials of the grouped sectors S1 through S8 against their energy-consumption percentages for the years 1999, 2000, 2001, and 2005 (Table 3), by assuming that ES-potentials do not vary over these years. In the absence of any other ES-potential data this is the best that can be done. Fig. 3 confirms that the grouped manufacturing sectors consuming more energy were identified also as potential energy savers by the EIE (Kavak, 2005). There seems to be a power-law (dashed curve) like relationship between the ES potentials and energy consumptions among the grouped manufacturing sectors of Turkey, and this relationship looks stable over the years. The contributions of all sectors, except S2 and S7, to Turkey's manufacturing-sector energy consumption are almost unchanged over these years. Energy-consumption percentage of S2 (textile and leather) was almost constant during 1999-2001, but almost doubled in 2005. On the other hand, the highest energy-consuming sector S7 (iron-steel) decreased its contribution to Turkey's manufacturing-sector energy consumption significantly over the years. Considering the highest energy-intensive cement-glass (S6) and iron-steel (S7) industries, ES potential of S7 is significantly higher than that of S6 because the cement-glass industries in Turkey have already been much more technologically modernized and EE-conscientious, compared to the aged iron-steel industries.

Fig. 4 shows the approximate historical picture of energy-consumption percentages (Table 3) and innovations (Table 2) in Turkish manufacturing sector groups. It is an approximate picture since in the absence of yearly-matching data we associated the 1999, 2000, 2001 energy consumption data with the innovation data for the periods 1995-1997, 1998-2000, 2002-2004, respectively. Stability of the sectors with respect to energy consumptions during the 1999-2001 periods is firm as discussed above via Fig. 3. Innovation-wise, sector S5 (chemical, petroleum, coal, plastics industries) shows significant shrinkage in the 1998-2000 recession period. The effect of economic recession on innovation activities of the other sectors (with the exception of S1, S3, and S8) is in the same direction but less severe compared to S5, Interestingly, 1998-2000 economic recession had a significantly positive effect on the innovation activities of sector S1 (food, beverages and tobacco). Innovation levels of sectors S3 (wood and furniture) and S8 (fabricated metal products and machinery) were also slightly positively affected by the recession. In the 2002-2004 fast economic-recovery period, sectors S3 (wood and furniture), S4 (paper, publishing), S5 (chemical, petroleum, coal, plastics) showed significant increase in their innovation levels. On the other hand, sectors S1 (food, beverages and tobacco) and S8 (fabricated metal products and machinery) showed moderate shrinkage in their innovation activities. All other sectors were also slightly positively affected innovation-wise by the economic-recovery period. However, above all, the most important conclusion portrayed by Fig. 4 is that the energy-consumption percentages of the sector groups S1 through S8 did not show any significant changes despite greatly varying innovation levels during these three periods. In other words, the contributions of these sector groups to Turkey's manufacturing-sector energy consumption (energy-consumption percentages of sectors) are insensitive to their innovation activities, or their innovation activities have not been EE- and ES-oriented in the past.

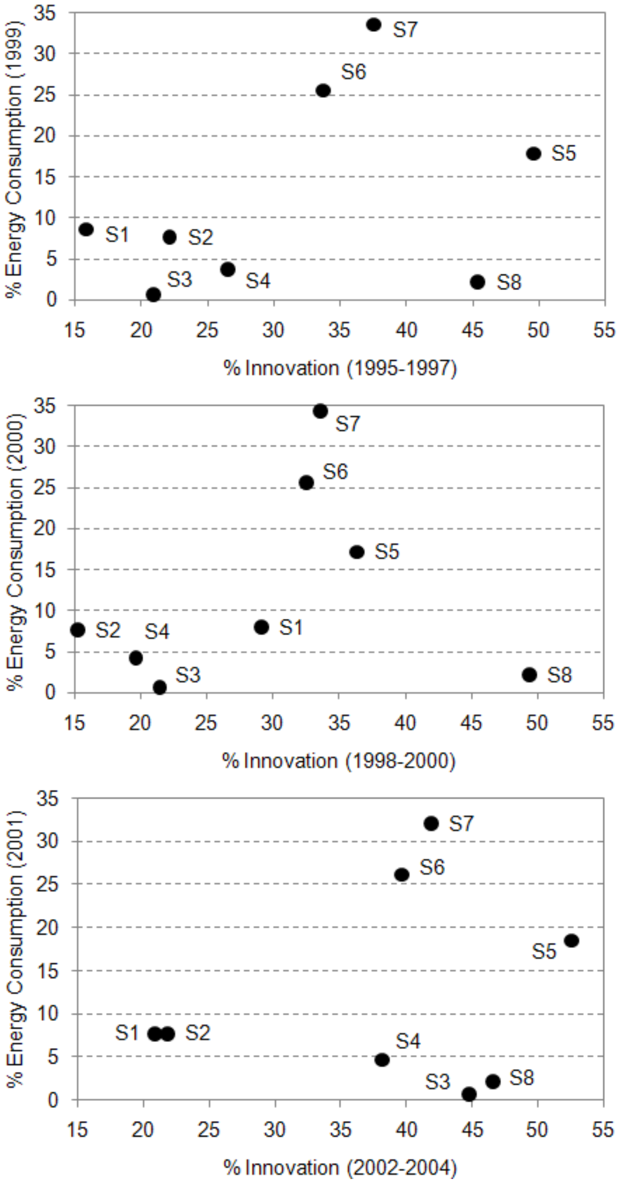

Fig. 4. Historical energy-consumptions and innovations in Turkish manufacturing sector groups.

In the bottom sub-plot of Fig. 4 we used the 2002-2004 innovation and 2001 energy-consumption data. In Fig. 5, we use the same latest innovation data (2002-2004) together with the latest energy-consumption data for the year 2005, with the presumption that the picture will represent the current situation more closely. Similar to the bottom sub-plot of Fig. 4, Fig. 5 also proves that innovation and energy-consumption percentages of the sectors are clustered. In the bottom cluster, energy consumptions and innovations of the sectors S3, S4, and S8, which are not energy-intensive, are uncorrelated. The sectors S6 and S7 in the top cluster are the most energy-intensive ones, and their innovations are also relatively high. Innovations of the sectors S1 and S2 as well as S6 and S7 should be enhanced and incited towards increasing their EE and ES.

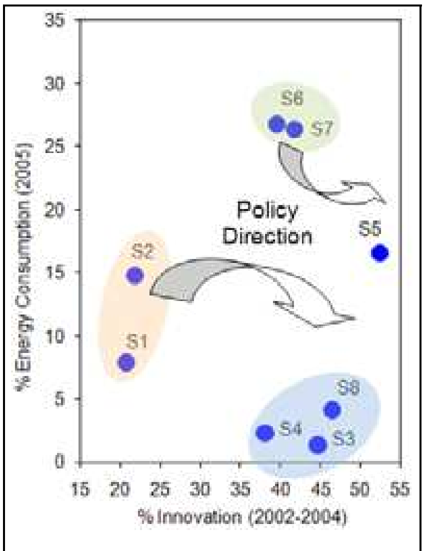

Fig. 5. Innovation and energy consumption in Turkish manufacturing sector groups.

Fig. 6 shows the ES potentials (Table 3) of the grouped sectors S1 through S8 against their innovation histories for the periods 1995-1997, 1998-2000, and 2002-2004 (Table 2), by assuming that ES-potentials do not vary over these periods. In the absence of any other ES-potential data this is the best that can be done. Fig. 6 shows that as a whole innovation and ES potentials of the sectors are uncorrelated. If sectors S3 and S8 (with both the lowest projected ES potentials and lowest energy consumptions) are seen as outliers, other sectors exhibit a weak positive correlation between ES potentials and innovations. This is an unhealthy picture and may imply that, in assessing the ES potentials of the sectors, EIE (Kavak, 2005) could not fully explore the innovation potentials towards ES, or worse yet, EIE (one of Turkey's esteemed administrations) did not spot enough EE- and ES-oriented innovation activities and innovation potentials. As a country whose energy-imports bill contributes significantly to its current account deficit, Turkey should encourage and support projects towards improved and detailed assessment of ES potentials and EE- and ES-oriented innovation potentials in its manufacturing sector. This point should definitely be in the agenda of the implantation of the recent EE and R&D laws, with contribution from the up-and-coming ESCO market.

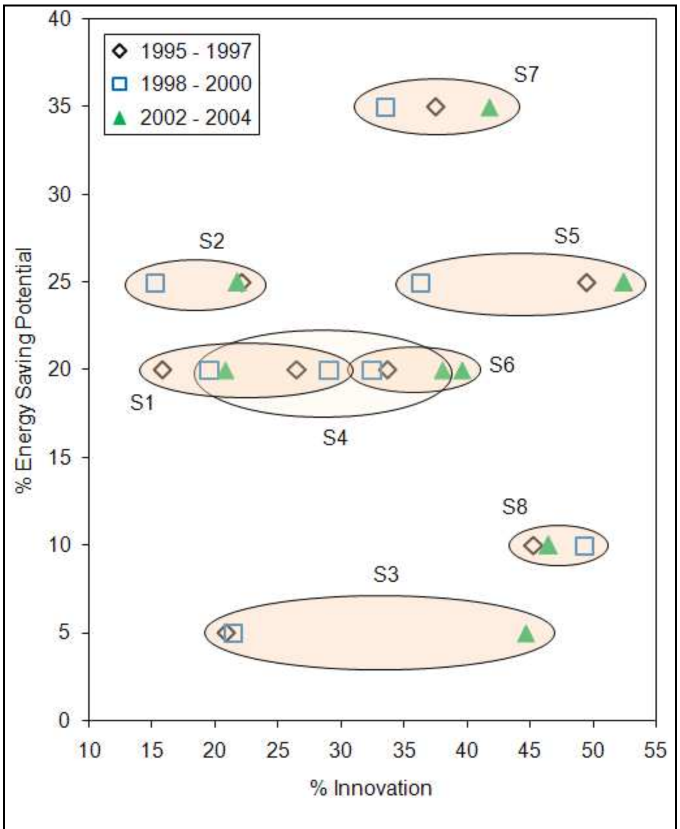

Fig. 6. Historical innovation and energy-saving-potential in Turkish manufacturing sector groups.

Fig. 7 is a radar chart that better reveals the whole picture by using the grouped manufacturing sectors S1 through S8 as the set of axes. The data on the chart were sorted with respect to the 2005 energy-consumption percentages of the sectors (Table 3), and only the 2002-2004 innovation data were used. Thus, the innermost line pertinent to the energy consumptions initiates close to the origin (S3, 1.3%) and spirals out clockwise (up to S6, 26.7%). The iron-steel industry (S7) shows itself with energy consumption, saving potential, and innovation percentages that are all high. The gap between the innovation and energy-consumption lines of the sectors S6 and S7 is almost constant,

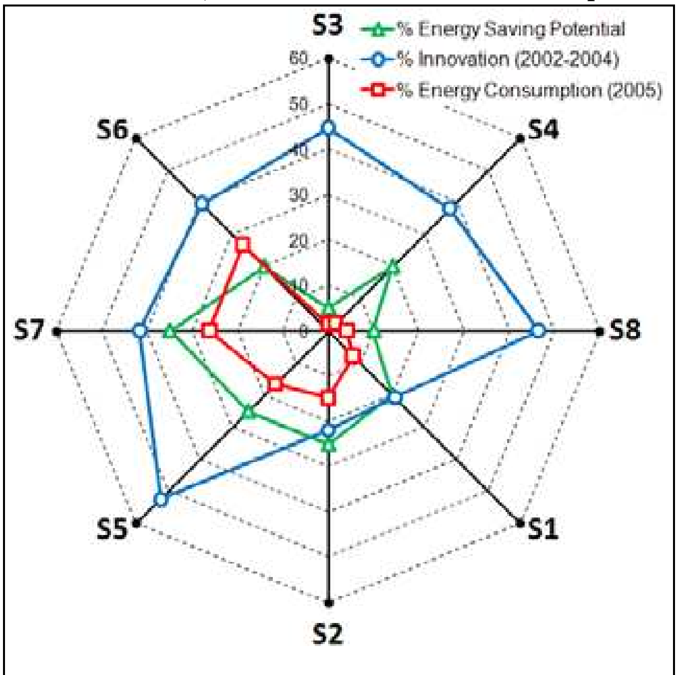

Fig. 7. Innovation, energy-consumption, and energy-saving-potential in Turkish manufacturing sector groups.

whereas the ES potential of S6 (cement-glass industry) is lower than that of S7. One of the most innovating sector S8 has low ES potential and very low energy-consumption. With the exception of sectors S4 and S6, the ES-potential curve is also clockwise correlated with the energy-consumption curve. However, there seems to be no correlation between the innovation curve and the other two curves in clockwise direction. This may give a hint to conclude that innovation activities and expenditures of the sectors, in general, are not sufficiently energy-oriented or there is no significant correlation between energy consumption and innovation activities. In an ideal case where EE- and ES-oriented innovation activities take a deserving part in innovation intensity of the manufacturing sector, the innovation curve should also show certain clockwise correlation. Increasing public and sectorwise awareness of energy-deficit problem of Turkey and dissemination of success stories and innovation models from other countries, demonstrating how rewarding the EE- and ES-related innovation and R&D activities may be, will help correct the picture. All of this can be done in awareness-rising mission already embedded in the recent EE and R&D laws of Turkey.

6. Views and policy suggestions

As a developing country, with newly establishing R&D-/innovation-related law and very much supply oriented energy policy in the past, directing the innovation and R&D activities towards ES, EE, and emission-reduction issues in the manufacturing sector of Turkey demands close monitoring and support from the government side in the short run. In the long run, expanding university-industry relationships and the prospective ESCO market (Okay et al., 2008) should bear parts of the burden. Turkey must direct its limited energy-policy related funds primarily to the manufacturing sectors exhibiting high energy consumption, high ES potential, and high competence in R&D and innovation activities. Innovation flourishes as a consequence of knowledge accumulation and R&D experience, all of which also expedite compliance with laws and regulations. Thus, in the short run, it will be more beneficial to direct the government funds aiming at EE to sectors with high potential of ES that are also accustomed to R&D and innovation activities. In this way, there will be more chance for successful completion of ES and EE projects, and efficient use of limited funds will be guaranteed. As a developing country, innovation activity in the entire manufacturing sector is far from a satiation point. In the long run, as this satiation point is approached for the above-mentioned energy-intensive sectors with high ES and innovation potentials, it will then become beneficial to direct the EE-related funds to sectors whose energy-related innovation activities are far from their satiation points, experiencing increased energy consumption, and demonstrating increased R&D and innovation activities.

To be specific about Turkey's case, in the order of decreasing energy consumptions, the manufacturing sectors S6 (cement-glass), S7 (iron-steel), and S5 (chemicals-petroleum) are the ones that must be supported for energy-related innovation activities in the short run with high priority. On the other hand, the sectors, in the order of increasing energy consumption, S3 (wood-furniture), S8 (fabricated metals products, machinery, automotive), S4 (pulp-paper), S1 (food-beverages), and S2 (textile-leather) should be the ones that must be supported for energy-related innovation activities in the long run, as the innovation satiation points for the formers (S5, S6, S7) are approached.

Past and current GDP-energy-emission relationships show that Turkey is still on the left branch of the inverted-U-shaped energy and environmental Kuznets curves, i.e. per-capita energy-consumption versus GDP and per-capita emission versus energy-consumption trends are linear with positive slope, and apparently far from a turning point. This shows that Turkey's manufacturing technology is not energy-efficient, and current R&D and innovation activities are not very much concerned with ES, reflecting Turkey's past supply-oriented energy policy. However, recent laws on EE and R&D/innovation aim to revert this policy towards being efficiency-oriented. If the R&D, innovation, and EE issues really matter for Turkey, then innovation and energy statistics must be expanded, energy-related innovation data should be collected, and energy-related innovations and R&D should be particularly supported by various funds and tax incentives in the manufacturing sectors. Legislations that will follow the recent R&D-/innovation-related law of Turkey should therefore include articles concerning energy-related R&D and innovations, demarcating support, funding, and tax-granting mechanisms for such expenditures of the manufacturing companies. Recently, Soytas and Sari (2009) also mention that Turkey is facing an investment problem and regardless of which alternative energy sources she wants to develop or utilize, a large portion of this investment would be through accumulating capital based on imported technology. They conclude that in order to reduce dependence on imports, Turkey needs to adopt a strategic long-term plan in technology development.

One important facet of Turkey's recent EE law is the establishment of an ESCO market. Views on Turkey's impending ESCO market and its role and relationships with the universities and R&D centers had been given by Okay et al. (2008). Here, we want to append to this topic that ESCOs should be encouraged and specifically supported for their activities that will involve energy-related innovation, and the transfer and establishment of new (renewable) energy technologies for the Turkish manufacturing industries. Turkish government must support and develop a shared vision of energy-related innovation between industry, universities, government-based R&D centers, ESCOs, and related foreign direct investment (FDI). Turkey's problem with FDI is that current account deficit (CAD), in which energy imports contribute significantly, is large and getting larger (CBRT: Central Bank of the Republic of Turkey: http://evds.tcmb.gov.tr); restricting the motivation of long-term FDI. Realization of ES potential via energy-related innovations should help reduce this portion of the CAD, and in turn, should encourage FDI flow to the country. Reduction in the CAD via successful energy-related innovations is expected to create an induced positive recurring effect on FDI flow.

The place of ESCOs in the organizational structure of the EEL of Turkey had been depicted and discussed in detail elsewhere (Okay et al., 2008). Here, with Fig. 8, on the condensed organizational structure of the EEL, we indicate the probable and most promising locations that may induce EE- and ES-related innovations taking synergy from the recent R&D law of Turkey.

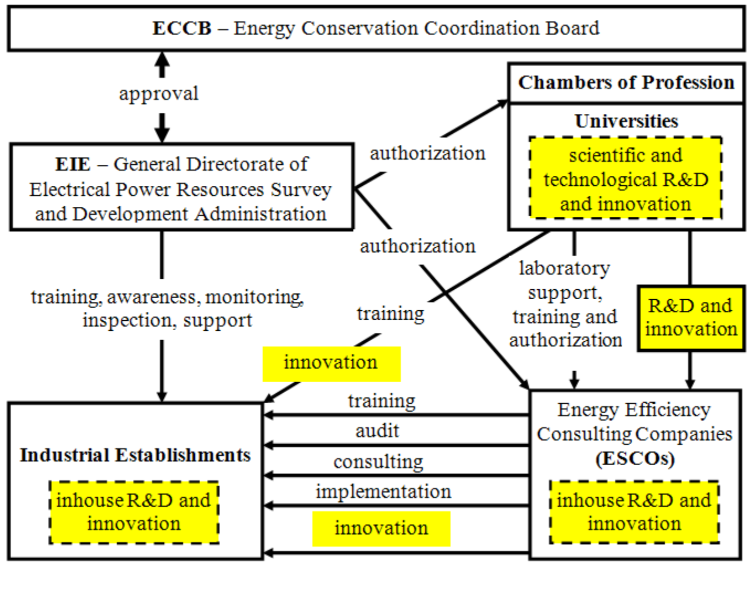

Fig. 8. The places of innovation sources in the organizational structure of the EEL of Turkey.

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References

Anderson, S.T., Newell, R.G., 2004. Information programs for technology adoption: the case of energy-efficiency audits. Resource and Energy Economics 26, 27-50.

Beerepoot, M., Beerepoot, N., 2007. Government regulation as an impetus for innovation: Evidence from energy performance regulation in the Dutch residential building sector. Energy Policy 35, 4812-4825.

Berndt, E.R., Kolstad, C.D. Lee, J., 1993. Measuring the energy efficiency and productivity impacts of embodied technical change. The Energy Journal 14, 33-55.

Bosseboeuf, D., Lapillonne, B., 2006. Assessment of energy saving potentials. Debriefing for the Twinning Project "Improvement of Energy Efficiency in Turkey", Mission to Ankara, (28 May - 1 Jun 2006), Ankara, Turkey, 1-21. < www.eie.gov.tr/turkce/en_tasarrufu/uetm/twinning/sunular/EE_tahmin/TREE_Pres_Act2-3_May06_DataBase_followup_Bosseboeuf_Lapillonne_v2.pdf >

Ediger, V.S., Huvaz, O., 2006. Examining the sectoral energy use in Turkish economy (1980-2000) with the help of decomposition analysis. Energy Conversion and Management 47, 732-745.

Elci, S., 2003. Innovation policy in seven candidate countries: the challenges – Innovation policy profile: Turkey. Final Report, Vol. 2.7, Enterprise Directorate - General Contract N°INNO-02-06 < www.innovation.lv/ino2/publications/final_report/turkey_final_report_march_2003.pdf >

Elliott, R.N., Pye, M., 1998. Investing in industrial innovation: a response to climate change. Energy Policy 26, 413-423.

Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A., Anderson, D., 2005. UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures Energy Policy 33, 2123-2137.

Hekkert, M.P., Harmsen, R., de Jong, A., 2007. Explaining the rapid diffusion of Dutch cogeneration by innovation system functioning. Energy Policy 35, 4677-4687.

Hepbasli, A., Ozalp, N., 2003. Development of energy efficiency and management implementation in the Turkish industrial sector. Energy Conversion and Management 44, 231-249.

Hepbasli, A., Utlu, Z., 2004. Comparison of Turkey's sectoral energy utilization efficiencies between 1990 and 2000, Part 2: Residential-commercial and transportation sectors. Energy Sources 26, 1345-1355.

Karaoz, M., Albeni, M., 2005. Dynamic technological learning trends in Turkish manufacturing industries. Technological Forecasting and Social Change 72, 866-885.

Kavak, K., 2005. Energy efficiency in the world and Turkey and investigation of energy efficiency in Turkish industry, Thesis for Planning Expertise, General Directorate of Economic Sectors and Coordination, State Planning Organization, Publication No: 2689 (in Turkish). < http://ekutup.dpt.gov.tr/sanayi/verimlil/kavakk/enerji.pdf >

Kemfert, C., Truong, T., 2007. Impact assessment of emissions stabilization scenarios with and without induced technological change. Energy Policy 35, 5337-5345.

Linn, J., 2008. Energy prices and the adoption of energy-saving technology. Economic Journal 118, 1986-2012.

Mountain, D.C., Stipdonk, B.P., Warren, C.J., 1989. Technological innovation and a changing energy mix - A parametric and flexible approach to modeling Ontario manufacturing. The Energy Journal 10, 139-158.

Mulder, P., de Groot, H.L.F., Hofkes, M.W., 2003. Explaining slow diffusion of energy-saving technologies; a vintage model with returns to diversity and learning-by-using.

Resource and Energy Economics 25, 105-126.

Newell, R., Jaffe, A., Stavins, R., 1999. The induced innovation hypothesis and energy-saving technological change. The Quarterly Journal of Economics 114, 941-975.

Nijkamp, P., Rodenburg, C.A., Verhoef, E.T., 2001. The adoption and diffusion of environmentally friendly technologies among firms. International Journal of Environmental Technology and Management 1, 87-103.

Oikonomou, V., Becchis, F., Steg, L., Russolillo, D., 2009. Energy saving and energy efficiency concepts for policy making. Energy Policy (in press).

Okay, E., Okay, N., Konukman, A.E.S., Akman, U., 2008. Views on Turkey's impending ESCO market: Is it promising? Energy Policy 36, 1821-1825.

Popp, D., 2001. The effect of new technology on energy consumption. Resource and Energy Economics 23, 215-239.

Popp, D., 2002. Induced innovation and energy prices. American Economic Review 92, 160-180.

Popp, D., Newell, R.G., Jaffe, A.B., 2009. Energy, the environment, and technological change, National Bureau of Economic Research (NBER) Working Paper 14832, 1-74. < http://www.nber.org/papers/w14832 >

Sari, R., Soytas, U., 2004. Disaggregate energy consumption, employment and income in Turkey. Energy Economics 26, 335-344.

Sagar, A.D., Holdren, J.P., 2002. Assessing the global energy innovation system: some key issues. Energy Policy 30, 465-469.

Soytas, U., Sari, R., 2007. The relationship between energy and production: Evidence from Turkish manufacturing industry. Energy Economics 29, 1151-1165.

Soytas, U., Sari, R., 2009. Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. Ecological Economics 68, 1667-1675.

Sterner, T., 1990. Energy efficiency and capital embodied technical change: the case of Mexican cement manufacturing. The Energy Journal 11, 155-167.

Sue Wing, I., 2008. Explaining the declining energy intensity of the U.S. economy. Resource and Energy Economics 30, 21-49.

Tunc, G.I., Turut-Asik, S., Akbostanci, E., 2009. A decomposition analysis of CO_2 emissions from energy use: Turkish case. Energy Policy (in press).

Utlu, Z., Hepbasli, A., 2004. Comparison of Turkey's sectoral energy utilization efficiencies between 1990 and 2000, Part 1: Utility and industrial sectors. Energy Sources 26, 1331-1344.

Uzun, A., 2001. Technological innovation activities in Turkey: the case of manufacturing industry, 1995-1997. Technovation 21, 189-196.

Table 1. Innovations and energy consumptions in Turkish manufacturing sectors

		% Innovative (% of firms innovating in each sector) [a]				**2005 Energy Consumption** [b]	
Sector ID	**Manufacturing Sector** (n.e.c.: not elsewhere classified), (#): NACE code	**1995-1997**	**1998-2000**	**2002-2004**	**1995-2004 Average**	**TOE**	**%**
MS1	food products and beverages (15)	20.26	38.10	29.45	29.3	1,407,969	7.709
MS2	tobacco products (16)	11.43	20.00	12.08	14.5	29,483	0.161
MS3	textiles (17)	23.18	17.90	25.78	22.3	2,289,299	12.534
MS4	wearing apparel; dressing and dyeing of fur (18)	7.32	18.70	21.93	15.9	327,896	1.795
MS5	tanning and dressing of leather; luggage, handbags, saddlery (19)	35.90	8.90	17.66	20.8	82,828	0.454
MS6	wood and products of wood and cork, except furniture (20)	9.14	27.60	42.62	26.4	165,407	0.906
MS7	pulp, paper and paper products (21)	23.71	20.70	53.00	32.3	388,843	2.129
MS8	publishing, printing and reproduction of recorded media (22)	29.20	18.50	23.10	23.6	29,154	0.160
MS9	coke, refined petroleum products and nuclear fuel (23)	65.22	31.60	69.43	55.4	1,707,629	9.350
MS10	chemicals and chemical products (24)	47.29	44.40	52.63	48.1	1,053,261	5.767
MS11	rubber and plastic products (25)	36.08	32.80	35.31	34.7	265,672	1.455
MS12	other non-metallic mineral products (including cement and glass) (26)	33.65	32.50	39.58	35.2	4,881,953	26.730
MS13	basic metals (27)	37.46	33.50	41.79	37.3	4,807,901	26.324
MS14	fabricated metal products, except machinery and equipment (28)	27.54	35.00	40.00	34.2	189,876	1.040
MS15	machinery and equipment n.e.c. (29)	34.99	50.80	52.17	45.9	152,155	0.833
MS16	office machinery and computers (30)	66.70	66.70	35.62	56.3	510	0.003
MS17	electrical machinery and apparatus n.e.c. (31)	38.10	66.60	37.80	47.5	80,800	0.442
MS18	radio, television and communication equipment and apparatus (32)	47.06	37.20	80.61	54.9	29,885	0.164
MS19	medical, precision and optical instruments, watches and clocks (33)	78.57	50.00	42.61	57.1	6,748	0.037
MS20	motor vehicles, trailers and semi-trailers (34)	38.17	25.10	59.83	41.0	259,382	1.420
MS21	other transport equipment (35)	31.20	62.60	23.33	39.0	29,273	0.160
MS22	furniture; other manufacturing n.e.c. (36)	32.67	15.20	46.72	31.5	78,126	0.428
Manufacturing sector average innovation (%)		35.2	34.3	40.1	36.6	18,264,050	100
Average industrial energy-consumption growth rate (%)		12.6	4.8	8.9	8.8		
Average GDP growth rate of Turkey (%)		6.8	1.9	4.5	4.4		

[a] TSI: www.turkstat.gov.tr/VeriBilgi.do?tb_id=9 [b] TSI: www.turkstat.gov.tr/VeriBilgi.do?tb_id=11

Table 2. Innovations in manufacturing-sector groups of Turkey

Sector ID	Manufacturing Sectors Groups	% Innovative (% of firms innovating in each sector group) [a]				Sectors Included
		1995-1997	1998-2000	2002-2004	1995-04 Average	
S1	food, beverages and tobacco	15.8	29.1	20.8	21.9	MS1, MS2
S2	textile, wearing apparel and leather industries	22.1	15.2	21.8	19.7	MS3–MS5
S3	wood and wood products including furnish	20.9	21.4	44.7	29.0	MS6, MS22
S4	paper and paper products, printing and publishing	26.5	19.6	38.1	28.0	MS7, MS8
S5	chemicals and chemical petroleum, coal, rubber and plastic products	49.5	36.3	52.5	46.1	MS9–MS11
S6	non-metallic mineral products (including cement and glass) except products of petroleum and coal	33.7	32.5	39.6	35.2	MS12
S7	basic metal industries (iron and steel)	37.5	33.5	41.8	37.6	MS13
S8	fabricated metal products, machinery and equipment, transport equipment, professional and scientific measuring and controlling equipment	45.3	49.3	46.5	47.0	MS14–MS21

[a] TSI: www.turkstat.gov.tr/VeriBilgi.do?tb_id=9

Table 3. Energy consumptions and energy-saving potentials in manufacturing-sector groups of Turkey

Sector ID	% Energy Saving Potential [a]	Energy Consumption (TOE) [b]				% Energy Consumption			
		1999	2000	2001	2005	1999	2000	2001	2005
S1	20	1,335,101	1,294,102	1,165,254	1,437,452	8.62	8.05	7.77	7.9
S2	25	1,194,975	1,228,101	1,165,270	2,700,023	7.71	7.64	7.77	14.8
S3	5	103,561	107,676	106,641	243,532	0.67	0.67	0.71	1.3
S4	20	585,620	681,413	709,661	417,998	3.78	4.24	4.73	2.3
S5	25	2,768,340	2,766,393	2,779,456	3,026,562	17.87	17.20	18.52	16.6
S6	20	3,955,851	4,120,112	3,927,409	4,881,953	25.53	25.62	26.17	26.7
S7	35	5,202,642	5,530,927	4,823,752	4,807,901	33.58	34.39	32.15	26.3
S8	10	345,798	353,284	328,572	748,629	2.23	2.20	2.19	4.1
	Total	15,491,888	16,082,008	15,006,015	18,264,050	100	100	100	100

[a] Kavak (2005): http://ekutup.dpt.gov.tr/sanayi/verimlil/kavakk/enerji.pdf

[b] TSI: www.turkstat.gov.tr/VeriBilgi.do?tb_id=11