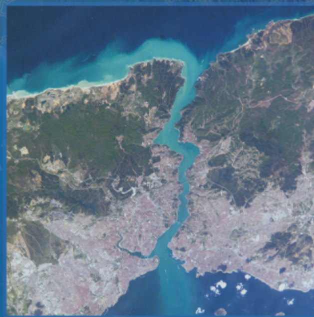
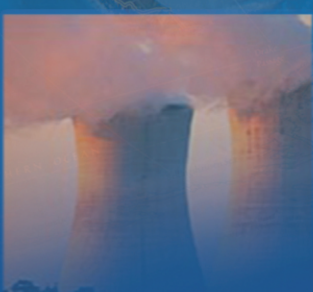
United Nations Development Programme

CLIMATE CHANGE & TURKEY

Impacts . Sectoral Analyses . Socio-Economic Dimensions





Climate Change & Turkey

Impacts, Sectoral Analyses, Socio-Economic Dimensions

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United Nations Development Programme

CLIMATE CHANGE & TURKEY

Impacts . Sectoral Analyses . Socio-Economic Dimensions

Edited by Prof. Dr. Çağlar Güven

CONTENTS

FOREWORD

There is increasing consensus among the scientific community that climate change is having a significant impact on habitats, ecosystems and human development. It is also generally accepted that the poor are disproportionately affected by the land, air and water degradation resulting from climate change and the accompanying reduced resilience of the ecological functions.

Ensuring environmental sustainability and access to safe water, energy and other services is key to achieving the Millennium Development Goals (MDGs) – the eight goals that represent a global commitment to make rapid progress in key development areas.

This publication integrates and synthesises the findings of various working groups headed by researchers, working closely with relevant national ministries, private sector representatives and NGOs. The report provides a comprehensive compilation of the research completed to support the preparation of the First National Communication (FNC) of Turkey to United Nations Framework Convention on Climate Change (UNFCCC). Readers are encouraged to contact the relevant references to obtain more detailed information.

This publication would not have been possible without the extraordinary commitment of the more than 100 national researchers and experts who contributed with their knowledge, their creativity, their time, and their enthusiasm to this process. We would like to express our gratitude to the members of the eight Technical Working Groups of the Climate Change Coordination Board led by the Ministry of Environment and Forestry, and supported by the UNDP/GEF project team.

We would like to thank the Technology Development Foundation of Turkey, which hosted the UNDP/GEF project team during the FNC preparation period.

We also would like to extend our thanks to TOBB (Union of Chambers and Commodity Exchanges of Turkey) for their generous support for this publication.

The global family is at a critical stage in its efforts to cope with the ravages wrought by climate change, and to slow down and reverse its devastation. Decisions made today will have a lasting impact on future generations. I sincerely hope that this publication contributes to the growing awareness on climate change issues, problems and potential responses at the local, national, regional and global levels.

On behalf of UNDP, I wish to thank all our partners for the productive and substantive dialogue surrounding the First National Communication. I also take this opportunity to reiterate our willingness and commitment to supporting Turkey's future endeavours in this critically important area.

Mahmood Ali Ayub
UN Resident Coordinator
UNDP Resident Representative

FOREWORD

Global Climate Change and the ripples of that change is affecting every aspect of life with ecological, economic and health dimensions. That is why the studies in this publication are not limited to impacts on health, water resources, agriculture, etc.

The burning of fossil fuels, which releases greenhouse gases such as carbon dioxide and methane, the unsustainable destruction of carbon-rich forests, and the use of heat-trapping aerosols are the main culprits behind the climate change phenomenon that could lead to unprecedented climatic changes in the coming decades.

The expected repercussions of climate change - including rising sea waters, more frequent and intense storms, the extinction of species, worsening droughts and crop failures - will affect every nation on earth.

The macro-economic analysis underlying the climatic dimension highlighted the argument that Turkey should take part in this platform in respect to its emission contribution on the basis of equity with other countries, in order to achieve global sustainable development goals. Researches obviously introduce that Turkey is not among those countries which greatly contributed to the increasing rate of climate deterioration. However, it needs to be aware of the global threat, including on cross-national borders and various sectors.

We believe that the analysis given in this report will guide Turkey in its policy making process, with a view to help slow down the climate change and re-stabilise the climate. Such work would also enhance Turkey's capacity to adapt to climate changes.

As being the representative of the business community in Turkey, TOBB recognize its responsibility and will fulfill whatever necessary for meeting this responsibility. Many in the business community have begun to understand the risks that lie ahead. With early action and innovative policies, business can enhance the world's capacity to adapt to change and ensure restabilize the climate.

I hereby would like to express my sincere wish that this fruitful cooperation with the Ministry of Environment and Forestry and United Nations Development Program will be recognized as another valuable asset for future partnerships.

M. Rifat Hisarcıklıoğlu

TOBB President

EXECUTIVE SUMMARY

The articles in this volume provide a record of the research on issues and problems brought about by climate change in Turkey. The research was commissioned to teams of academics and professionals to form part of a starting basis for Turkey's First National Communication Report and for building climate change policies as per UNFCCC operation. The work has been carried out mainly in 2006 and the articles appear in this volume in abridged form; authors should be contacted for full reports.

The articles are presented in three parts; bearing the titles: I. Impacts & Vulnerability Analyses, II. Sectoral Analysis & Potential Mitigation Measures, III. Socio-Economic Dimensions.

The first article in Part I, "Climate change scenarios for Turkey" by Dalfes, Karaca and Şen, reports firstly on trends in precipitation and temperature in Turkey since 1951. Based on data from 113 stations of the State Meteorological Service, the authors observe that winter precipitation in western Turkey has decreased significantly whereas autumn precipitation has increased at stations in the northern parts of central Anatolia. The reason behind these changes is not well understood, and the need for more comprehensive study is underlined. The authors report widespread increase in summer temperatures mostly in the western and southwestern parts of Turkey while winter temperatures show a general tendency to decrease. The more significant changes are concentrated in coastal stations. Streamflow data based on measurements from 1969 to 1998 indicate a decreasing trend in western and southwestern regions and some increase in the north. The second part of the article presents results from the use of the RegCM3 climate model and downscaling runs using modelling and as well as statistical techniques. Model simulations appear to be corroborated by observations demonstrating scope for model use in scenario formation and policy making. Authors point out that a lot remains to be done on model use such as achieving finer resolutions for local predictions before useful scenarios can be defined.

Two articles follow, that look into the effects of climate change on the hydrology and the ecosystem of two major basins of Western Anatolia. "Modelling for climate change effects in the Gediz and Büyük Menderes basins" by Harmancıoğlu, Özkul, Fıstıkoğlu, Barbaros, Önusluel, Çetinkaya and Dalkılıç follows a path similar to that of the previous article at a regional level. Their analyses reveal significant downward trends likely to cause serious water supply problems in the future concluding that the possible effects of climate change in each basin would be to amplify existing scarcity and allocation problems. Authors use climate models that predict an increase of 1.2^{0}C in mean annual temperature, and a decrease of 5% in mean annual precipitation by 2030 that rises to 2^{0}C and 10% respectively in 2050. Although decreases are expected in precipitation in all months, the sharp decreases in spring and autumn are significantly important, because summers in the region are already dry. Simulation results of a water budget model is reported to show nearly 20% reduction of surface waters by 2030 causing serious water stress problems among water users. Furthermore the authors report, increasing crop evapotranspiration will increase irrigation water demand enormously.

A second paper "Effects of climate change on the ecosystem of Büyük Menderes" by Kazancı explores changes in the composition of macroinvertebrate taxa of Büyük Menderes under a base case scenario extrapolated from the findings of the first article of Part I.

The next 2 papers in Part I address possible health effects of climate change. "Correlation between temperature, rainfall and leptospirosis incidence in İstanbul" by Polat, Turhan, Çalışkan and Alan shows that increases in air temperatures and rainfall, together with changes in the ecosystem are significant factors in the emergence of leptospirosis even in metropolitan centres. Understanding the linkages between climatological and ecological change as determinants of disease emergence and redistribution the authors say, will ultimately help optimise preventive strategies. They also point out the need for similar studies over a broader time frame and in different regions.

"Correlation between temperature and rainfall changes and malaria in Turkey" by Ergönül similarly points out a relation between higher temperatures and malaria incidence although the results are somewhat confounded with effective preventive measures indicating the need for further study.

Part II includes three papers on mitigating the effect of CO_2 emissions in the industry and services. In "Estimating carbon dioxide emissions in the Turkish iron and steel industry" Durlu, Übeyli, Tekin and Sarıtaş first report on a survey to determine specific energy consumptions as well as specific CO_2 emissions for the years 1990, 2004, 2010, 2015 and 2020 from which they estimate total emissions. Their results show that in 1990, total CO_2 emissions related to direct use of energy in steel production is estimated to be 11.96 Mt. Only a small proportion of this came from electric arc furnace technology, while the rest emanated from integrated steel plants. Production amounted to 20.50 Mt of crude steel in 2004, with CO_2 emissions of 15.2 Mt., 13% of which came from arc furnaces and the rest from integrated plants. The relative improvement observed in integrated plants was due to 20 to 25% reductions in specific energy needs made possible by efficiency measures and investments. Crude steel production is expected to increase to 28.37 Mt in 2010, 32.36 Mt in 2015, and 33.86 Mt in 2020 and further reduction in the specific emission values can be expected within this period decreasing from 1.91 ton CO_2/ton crude steel in 2010 to 1.87 tons in 2015 and 2020. In conclusion the authors state, with ongoing investments for lower specific energy consumption and hence lower specific CO_2 emissions in the next 15 years, the industry will be in better shape in terms of product quality and of emitting less CO_2 per ton of output.

In "Greenhouse gas emissions in the transport sector in Turkey", Soruşbay and Ergeneman compute in considerable detail, CO_2 emitted by transportation activities of all modes. Total emissions have increased from 25,954.63 Gg in 1990 to 40,457.82 Gg in 2004, or by 55.8%. This corresponds to a change from 0.46 ton CO_2/capita in 1990 to 0.57 ton CO_2/capita in 2004, and given that vehicle ownership has further room to grow, total emissions must be expected to rise. The authors also compute however that emissions have been reduced from 0.17 kg CO_2/\$ in 1990 to 0.14 kg CO_2/\$ in 2004 in the sector, pointing out the room for improvement through attaining higher efficiencies in energy use.

Sustainable transportation in Turkey as in the rest of Europe they say, can be achieved through technological changes that result in improvements of existing vehicle and engine technologies and development of new, less polluting fuels, engines and vehicles. Parallel to technological developments for vehicles, demand for transportation also has to be managed and reduced to a certain extent by shifting traffic towards non-pollutant or low-pollutant modes such as public transport, rail systems, bicycles or pedestrian areas in urban regions.

"National transport rehabilitation in Turkey" by Gerçek builds upon Soruşbay and Ergeneman and provides projections around a growth scenario. Emission calculations for the period from 2005 to 2020 are both fleet based and demand based and take into consideration modal shifts from road to rail transport. The author indicates that fleet based projections can be controlled by encouraging early retirement of old and substandard vehicles. Total emission projections for several GHGs are obtained by demand based calculations; CO_2 emissions are projected to increase from 44.89 Mt in 2005 to 104.72Mt in 2020. Emission figures obtained using fleet based projections are considerably higher than those that are demand based indicating the need for further analysis. In terms of mitigation policies the paper lists operational, strategic and demand management measures that seek to reduce energy use per vehicle-km, to optimise vehicle use to reduce total vehicle-km per passenger-km and to reduce the overall demand for travel. A number of policy instruments are listed that include pricing and taxation and other arrangements. The paper concludes by observing that the transportation sector can meet the requirements of sustainable development provided that there is political will and determination to solve the problems together and coherence between EU policies and economic, environmental, fiscal, social and budgetary policies, as well as town-and-country planning.

"Cost-benefit analyses for improving energy efficiency and reducing greenhouse gas emissions in the Turkish cement industry" as presented in Part III by Ercan, Durmaz, Çürüksulu and Daloğlu presents an in-depth analysis of the Turkish cement industry, identifies energy saving and CO_2 reduction potentials, and develops an implementation plan of the necessary measures based on cost-benefit analyses from 2004 to 2020. This work goes further than others in that mitigation policies are based on a partial-equilibrium type aggregated model of the industry that also takes into account costs and emissions resulting from electricity generation needed to produce cement. Different scenarios are defined depending on the intensity of technological measures to be adopted and approximate costs and benefits of each are computed, albeit in aggregated terms. Results are presented for two discount rates. Total CO_2 emission in the sector was 20.59 million tons in 1990 and then rose to 30.90 tons in 2004 . If production were carried out using the technology of 1990, total emission would have reached 33.29 million tons in 2004, indicating that emissions have been reduced by %7 as a result of voluntary measures taken during this period. Authors calculate in similar manner that if computed energy saving measures are implemented after 2004, total CO_2 emissions in 2020 would be 50.90 million ton-CO_2/year for 12% interest rate, compared to 54.63 million ton-CO_2/year with no measures taken. Specific energy consumption and emission levels are also computed under different policy assumptions. This work points out the scope for cost-effective mitigation policies and serves as a useful starting point for more detailed analyses.

"A general equilibrium investigation of the economic evaluation of sectoral emission policies for climate change" by Telli, Voyvoda and Yeldan included in Part III, seeks to provide an integrative platform for policy evaluation across the entire economy. This is an initial but significant effort to establish a framework capable of addressing tradeoffs between conflicting goals such as growth, employment and emission limits. A multi-sectoral computable general equilibrium model of the economy is constructed that disaggregates emission producing sectors and is used to evaluate various emission control measures such as imposing quotas through emission taxes and energy taxation. Policies involving abatement investments are also addressed albeit in approximate and aggregated terms. Analyses conducted suggest that the burden of imposing direct emission quotas would be substantial, necessitating for example a 20% to 15% carbon tax over the period from 2006 to 2020 in order to achieve a 60% emission reduction relative to the base run. Annual GDP losses such a scenario would cause could exceed 30% in 2020. In contrast, taxation of energy use in sectoral production is computed to produce a 25.8% cut in emissions in return for a 20% energy tax, resulting in an overall GDP loss of 8.8% in 2020. The authors point out however that energy taxation would suffer strongly from very adverse employment effects. Moving further into active abatement policies would call for further incentives towards reducing energy intensities in production through more efficient production methods that comes at significant investment cost. Results suggest that leaving the burden of abatement investments to produeates significantly adverse results in the form of 5% GDP reduction on the average per year. Authors also discuss the implications of government investments for abatement as well as foreign funding that may be available through the flexible mechanisms of the Kyoto protocol. These results are preliminary and tentative at the best and much remains to be done such as establishing causal links between sectoral abatement policies and macroeconomic analysis within the equilibrium framework rather than relying on aggregate assumptions about the link between investment needs and emission reductions. This work however provides a firm and very useful footing on which further and more detailed modelling can be based.

ACRONYMS

AG	Agricultural Production
BOF	Basic Oxygen Furnace
CE	Cement Production
CGE	Computable General Equilibrium
CO	Coal Mining
CSE	Cost of Saved Energy
DLH	General Directorate of Railways, Harbours and Airports Construction
DSI	State Hydraulic Works
EAF	Electric Arc Furnace
EL	Electricity Production
EC	European Commission
EU	European Union
GCM	Global Climate Models
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GWh	Gigawatt/hour
IPCC	Intergovermental Panel on Climate Change
IS	Iron and Steel Production
ISP	Integrated Steel Plant
LTO	Landing and Take Off
MENR	Ministry of Energy and Natural Resources
OE	Primary industry sectors and remaining manufacturing services
OECD	Organisation for Economical Cooperation and Development
OHF	Open Hearth Furnace
PA	Paper Production
PEP	Primary Energy Purchase Prices
PET	Potential Evapotranspiration
PETDER	Petroleum Manufacturers Association of Turkey
PG	Petroleum and Gas
PM	Particulate Matter
ppm	Parts Per Million
RP	Refined Petroleum
SPO	State Planning Organisation
SRES	Special Report on Emission Scenarios
TCDD	Turkish State Railways
TCS	Ton Crude Steel
TÇMB	Turkish Cement Manufacturers' Association
TFP	Total Factor Productivity
TR	Transportation
TRY	New Turkish Lira
TUBİTAK	Turkish Scientific and Technical Research Council
TURKSTAT	Turkish Statistical Institute
VOC	Volatile Organic Compound
WHO	World Health Organisation
UNDP	United Nations Development Programme

Part I:

IMPACTS & VULNERABILITY ANALYSIS

Modeling Studies on Natural Ecosystems and Health

CLIMATE CHANGE SCENARIOS FOR TURKEY

Prof. Dr. H. Nüzhet Dalfes
Prof. Dr. Mehmet Karaca
Assoc. Prof. Dr. Ömer Lütfi Şen

Eurasia Institute of Earth Sciences - Istanbul Technical University

1. Introduction – Scope and Context of the Study

This report includes the results of research on climate change in Turkey during the last century and developments in climate change projections made at the Eurasia Earth Sciences and Informatics Institutes of the Istanbul Technical University. We also report on the early phase of an ongoing and longer-term research programmeme supported by a TÜBİTAK (105G015) grant.

An attempt has been made to document how climatic variables such as precipitation and temperature have changed in Turkey in the past. We obtain long term precipitation and temperature data (daily, monthly, and yearly averages or totals) from the Turkish State Meteorological Service and performed quality control procedures and homogenisation tests on the data sets. Employing the Mann-Kendall test, we generate trends for precipitation and temperature (minimum, maximum and average) series. In addition, we apply the circular statistics approach to monthly precipitation data to characterise seasonality in terms of the average time of occurrence and the seasonality index, and investigate whether and how the seasonality of precipitation has changed in Turkey in the past.

The final aim of our current efforts is to obtain climate change projections at scales meaningful for impact studies on water resources, natural ecosystems, agricultural production systems, human health and the like. These studies require climate information at scales much finer than what global system models can generate with current computer technology and sub-grid scale process parameterisations.

Most of the work done throughout the project has targeted the dynamic downscaling of global-scale climate system models to scales of interest for impact studies. As will be detailed later, downscaling efforts using regional climate models should, among other things, assess model simulation performance against observed data.

On the front of statistical downscaling, our efforts concentrated on the selection of appropriate tools amongst the large plethora of existing methodologies. We implementing two of those methods: multiple linear regressions and canonical correlation pattern analyses.

When all uncertainties related to physically based or statistical downscaling are considered, the so-called 'projections' do not turn out to be directly useable products. This is where the scenarios come in: “a climate scenario refers to a plausible future climate that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change” (IPCC, 2001).

In this report, we consider and briefly describe the impacts of possible sea-level rise for Turkey. Unfortunately, there is not enough sea-level data covering temporal and spatial changes. Comments given here are based on compilation of previous studies.

Ultimately, the work described in the report will lead to a set of climate projections, rich enough to be combined to constitute the principal ingredient of climate scenarios for Turkey and its region., Alongside projections from climate models and statistically downscaled climate parameter change estimates, climate scenarios take also into account expert knowledge, to come up with a plausible, consistent sets of climate parameters that include best estimates about climate features such as extreme events. For all these reasons, it is preferable to make use of change scenarios rather then climate model outputs to investigate the future of the earth system.

2. Data Resources

It is well recognised that variations and trends in most long-term climatological time series are caused not only by changes in weather and climate but also by the relocation of the stations, or the alteration of the instruments, the observing practices or the station environment. Thus, before conducting a study of climate variability or investigation of a possible climate change signal using station data, a quality control and correction of data sets are mandatory. The Turkish station data have been subjected to rigorous quality control and homogenisation wherever necessary, before using in trend analyses for detection of any climate change signal (Bozkurt and Göktürk, 2006). The period for the analysis of the station data is taken as the 1951–2004 interval and the stations that do not fulfill this criterion are eliminated from the data set. The following steps describe the procedure followed in dealing with the missing values in the time series of both precipitation and temperature.

(i) Any missing value in the daily observations is kept as missing.
(ii) Monthly mean is calculated from daily means and is specified as missing when 20% or more of the daily means are not available.
(iii) For stations having less than 10% monthly missing data, the climatological mean of each month is used to complete the monthly series.
(iv) Seasonal and annual data are calculated from monthly data.

The data sets are then analysed for outliers, and those identified as outliers are reduced to a preset threshold value in accordance with Barnett and Lewis (1994). Finally, the series are analysed for non-climatic events that might have taken place during the operation of the stations, and detection and adjustment of such inhomogeneties are made following a procedure developed by Hanssen-Bauer and Forland (1994). The final data set consists of 113 stations whose distribution is depicted in Figure 1.

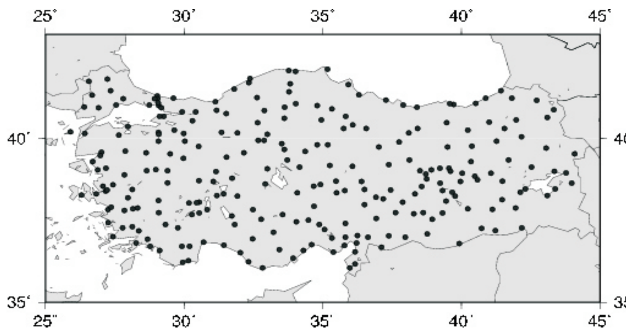


Figure.1 Distribution of Turkish climate stations used in trend studies.

3. Observed Climatic Changes

3.1 Trend Analysis

3.1.1 Precipitation

There is no doubt that any persistent change in the patterns of precipitation, or in the characteristics of precipitation such as the intensity, frequency or duration; would have significant consequences on the environment. Thus, global warming studies pay special attention to this crucial variable. There are, however, difficulties in identifying climate change signals in precipitation. Some of these difficulties are related to the quality of the data as precipitation measurements are prone to several types of errors. The length of the precipitation data brings in another difficulty in tracking the climate change signal since precipitation is temporally, as well as spatially, a highly variable parameter. Sometimes it is possible to detect a trend in a 'short' time series of precipitation, which, in reality, could be a part of the long-term variability.

Therefore, care has to be taken when interpreting the trend analysis of precipitation data. In the trend analysis, we deployed the commonly used nonparametric Mann-Kendall method to identify significant trends in the quality-controlled station data (e.g., Karaca et al. 1995).

Figure 2 illustrates the results of the Mann-Kendall test for four seasons. Coherent areas of significant changes in precipitation can be seen in both winter and fall seasons. Winter precipitation in the western provinces of Turkey has decreased significantly throughout the last five decades. Fall precipitation, on the other hand, has increased at stations that lie mostly in the northern parts of central Anatolia. The reason behind these changes is not well understood. They definitely require a comprehensive study, which should also look into the link between cyclone tracks and these changes (Karaca et al., 2000). In the spring and summers, there are only a few stations with statistically significant changes; still, they do not show a coherent regional behavior.

3.1.2 Temperature

Compared to precipitation, temperature is a variable that can be measured easily and more accurately at meteorological stations, therefore uncertainties coming from measurement errors are of lesser concern. Nonetheless, climate change signals in temperature are usually contaminated by the urbanisation effects because most of the stations in Turkey or elsewhere have been gradually encircled by city residential and/or commercial areas. It is therefore difficult to separate climate change signal from urbanisation effects on temperature time series.

Figure 3 shows the results of Mann-Kendall trend analysis applied to seasonally average annual temperature series between 1951 and 2004. The most prominent feature that one can observe is the widespread increase in summer temperatures. Summer temperatures increase mostly in the western and southwestern parts of Turkey.

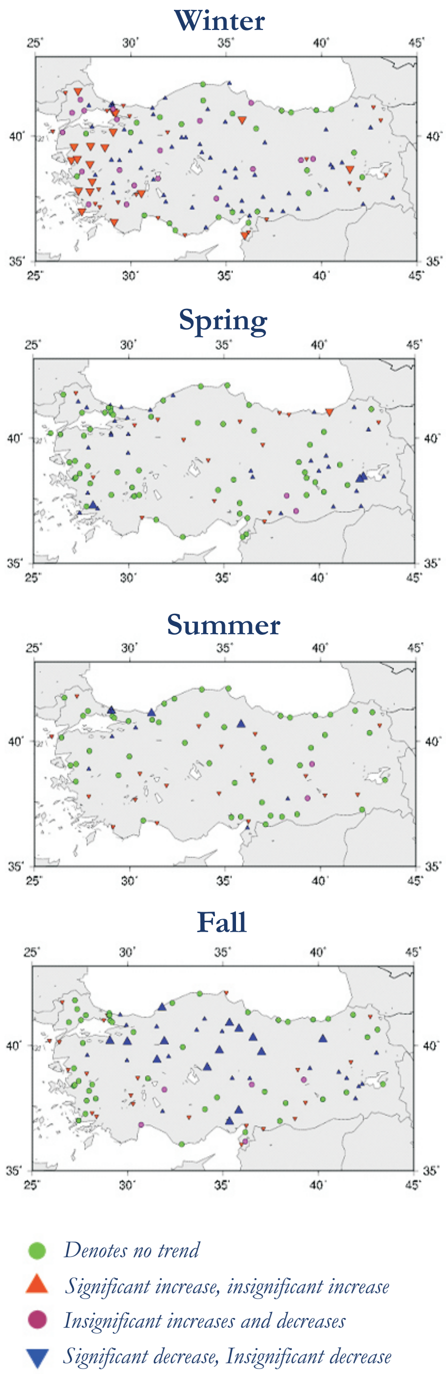


Figure. 2 Seasonal precipitation trends for the period 1951-2004.

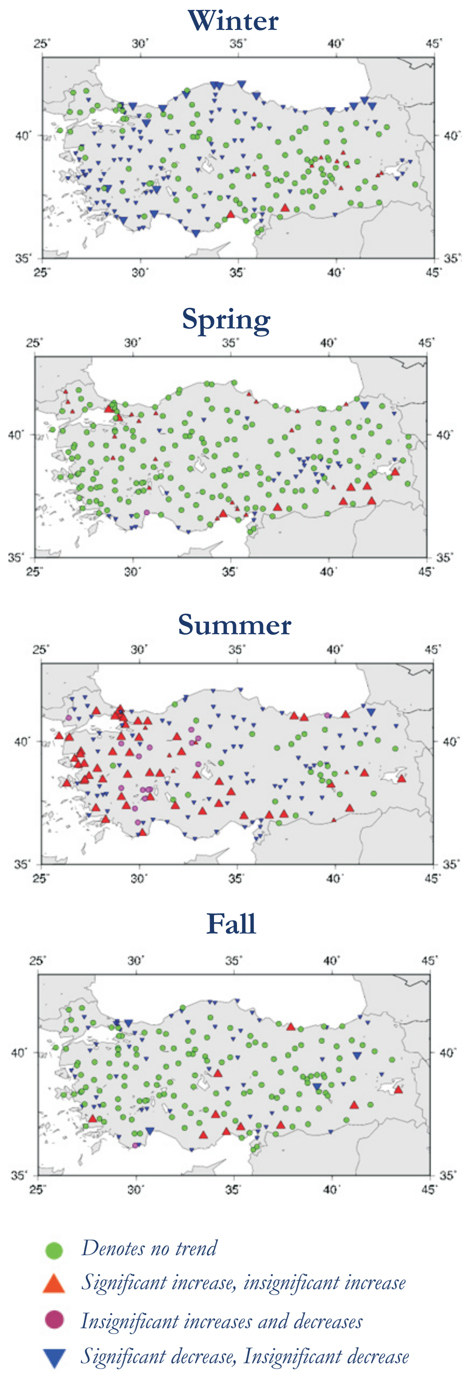


Figure.3 Seasonal temperature trends for the period 1951-2004..

Urban heat island studies (e.g. Ezber et al., 2006, and Karaca et al., 1995) indicate that temperature rise as a result of urbanisation is most notable in summer in Mediterranean cities when the region comes under the influence of high pressure systems. Thus, widespread increase in temperature in western stations in Turkey may be mainly related to this phenomenon. Winter temperatures also show a general tendency to decrease. It can be noted that the more significant ones are mostly concentrated in the coastal stations. During transition seasons, stations with significant trends are usually sporadic in nature, and they do not show a coherent regional behavior.

Figure 4 illustrates the seasonal maximum (first row) and minimum (second row) temperature trends for winter (left column) and summer (right column). The maximum temperatures for winter exhibit significant downward trends in the coastal stations of the Black Sea region and widespread decreasing tendency in the central Anatolian region (a). In summer, however, the general trend of maximum temperatures is in the increasing direction, particularly in western Turkey (b). Several stations in eastern Anatolia also show significant increases in maximum temperature. In general, the minimum temperatures depict similar distributions in both winter and summer. Winter minimums show significant decreases only in the northern and southern coastal regions (c). Summer minimums exhibit significant increasing trends at almost all stations that have observations in the period considered in this study (d).

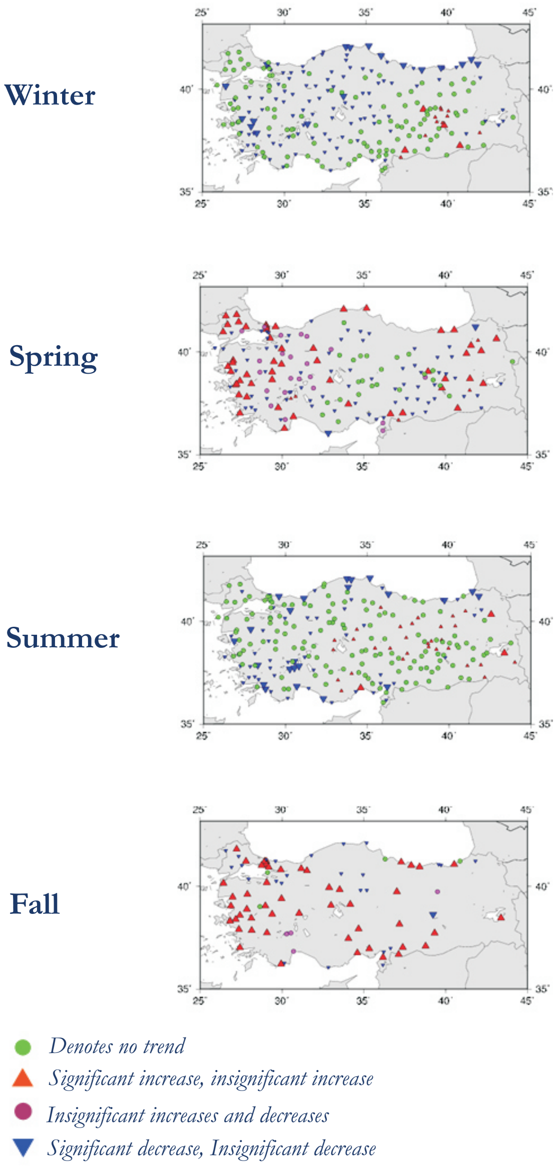


Figure.4 Seasonal maximum and minimum temperature trends for the period 1951-2004.

3.1.3 Streamflow

Streamflow has less uncertainty associated with its measurements compared to the measurements of precipitation. Nevertheless, the facts that the streamflow records taken in stream gauges are comparatively short and that the watershed characteristics and water withdrawal rates from rivers for irrigation and drinking purposes can change over time, all affect the quality and the homogeneity of the streamflow data to be used in the trend analysis. Therefore, we apply the same quality control and homogeneity procedures to streamflow data, as in precipitation, and eliminate all stations data that fails to pass the tests.

Figure 5 demonstrates the results of Mann-Kendall trend analysis for annual streamflow measured between 1969 and 1998 at various stream-gauge stations. It is clear from this figure that the streamflow exhibits significant decreasing trends in the western and southwestern parts of Turkey. There are a few stations at the northern parts where streamflow indicated significant increases. This distribution is more or less the same for all seasons.

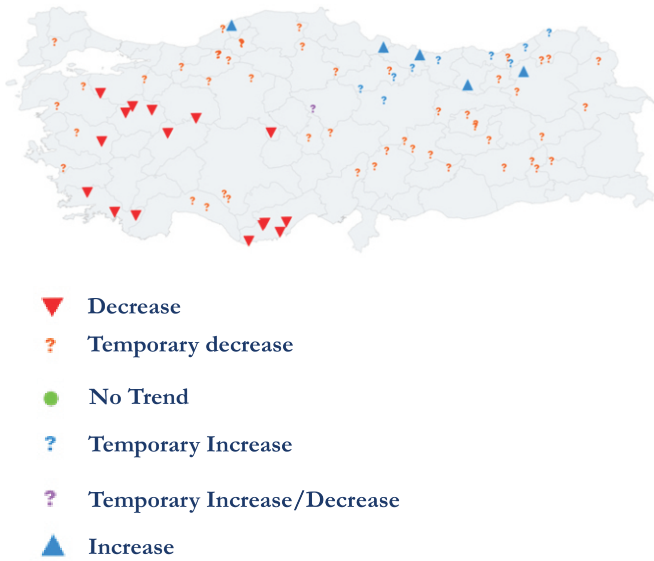


Figure.5 Results of Mann-Kendall trend analysis for annual streamflow (1969 - 1998).

3.2 Seasonal variability of precipitation

Seasonal variability of precipitation is an important aspect of hydroclimatology because it largely determines the seasonality of other hydrologic quantities, such as streamflow and groundwater recharge (Dingman, 2002). One way of quantitatively describing seasonality is by means of circular statistics as defined in Dingman (2002). We apply the circular statistics approach to monthly precipitation data to characterise seasonality in terms of the average time of occurrence and the seasonality index, and investigate whether and how the seasonality of precipitation has changed in Turkey in the past. Figure 6 shows both period (a to d) and degree (e to h) of concentration of precipitation for the 10-year periods, namely 1935-1944, 1955-1964, 1975-1984, and 1995-2004. These 10-year seasonality maps are produced to see whether any change has occurred in the seasonality of precipitation over a time period of 70 years. As can be seen from Figure 6a, b, c and d, Turkey in general receives much of its precipitation in winter. Precipitation makes a peak in January in southern and western parts of Turkey, in February and March in most of the central Anatolia, in December in northern Marmara region including Istanbul, in October and November in Black Sea coasts, and in May and June in far eastern parts. Degree of seasonal concentration of precipitation is the highest in the Mediterranean and Aegean coasts of Turkey, and it decreases towards Black Sea coasts (Figure 6e, f, g and h).

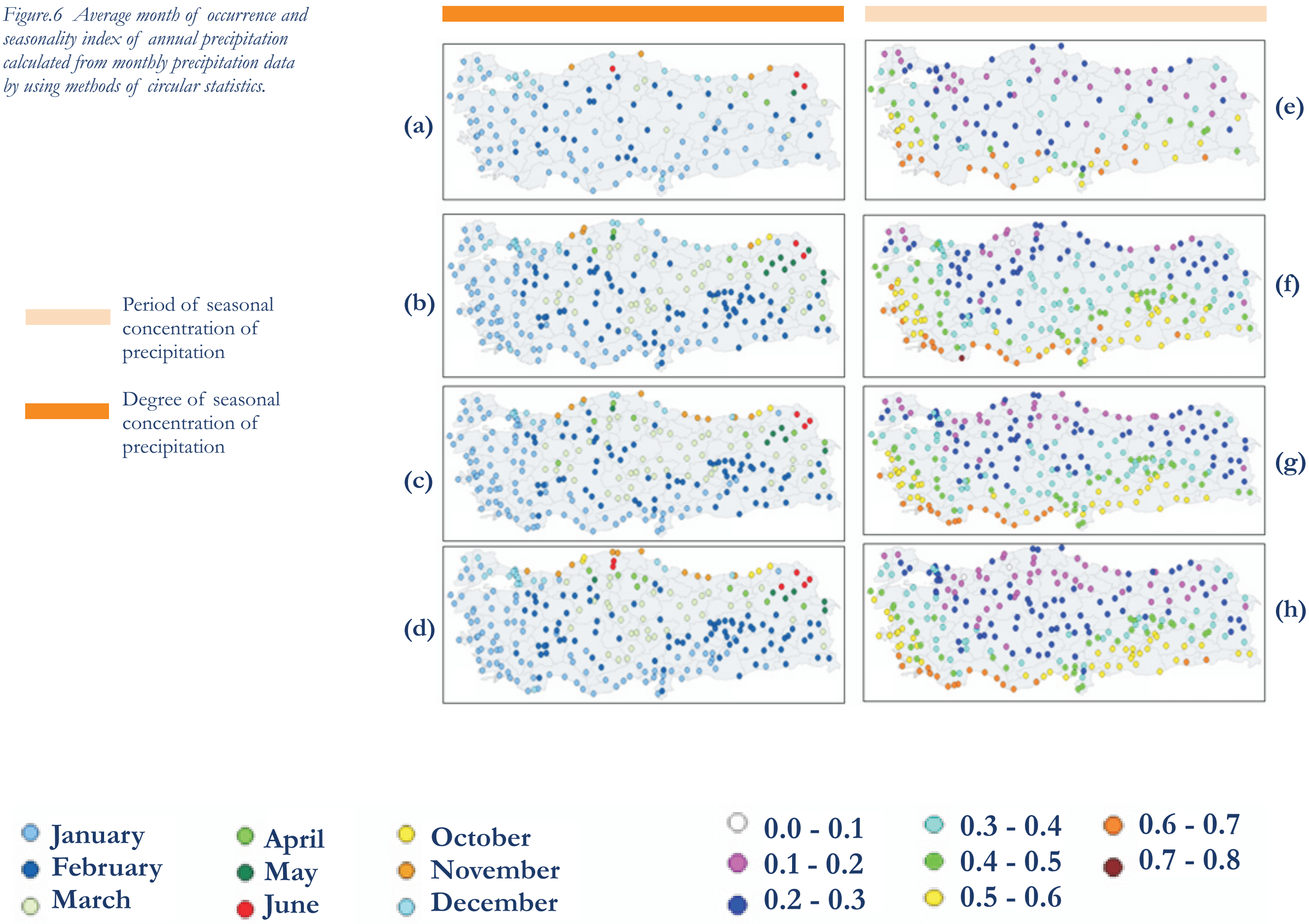


Figure.6 Average month of occurrence and seasonality index of annual precipitation calculated from monthly precipitation data by using methods of circular statistics.

It seems from these plots that the general picture of seasonality of precipitation has remained constant during the last 70 years. However, one can notice some changes when one looks at the station level. Most of these changes indicate one month forward or backward shifts (a to d). The degree of seasonal concentration of precipitation decreases in the central parts of Turkey over the period considered in this analysis (e to h).

4. Methodological Approaches

4.1 Dynamic Downscaling

4.1.1 Studies Using RegCM3

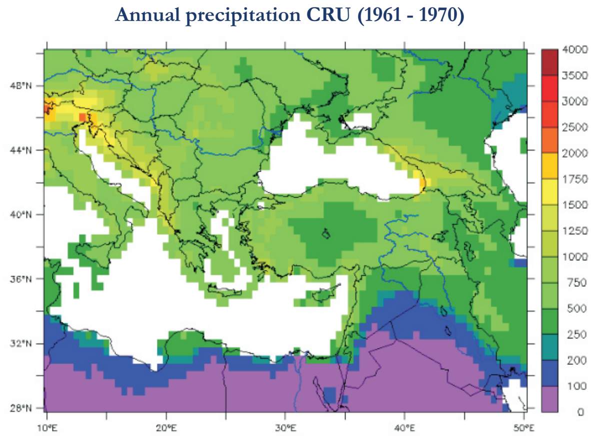
RegCM3 is the third version of a regional climate model developed by and is maintained at the International Centre for Theoretical Physics, in Trieste, Italy. RegCM was originally built upon the National Center for Atmospheric Research-Pennsylvania State University (NCAR-PSU) Mesoscale Model version MM4 in the late 1980s. Since then, there has been major improvement in the physics of the model and the associated software, which made it a popular tool for regional climate studies.

Downscaling studies using RegCM3 are conducted by one of our team member, Barış Önol, at the Department of Marine, Earth and Atmospheric Sciences of the North Carolina State University in Raleigh, NC, USA.

A series of tests have been conducted to determine an optimal horizontal resolution, and a resolution of 30 km is chosen. This is a somewhat subjective choice; computational resources and Turkey's mountainous topography had to be considered. In the future, we plan to run the model at higher resolutions for smaller domains and seasons of interest to asess the impact of topography on model results. Also, there are a multitude of options for the 'physics' used in the model: Grell scheme has been chosen for cumulus parameterisation and Arakawa-Schubert as the closure scheme.

At the moment, two sets of simulations have been conducted: control runs forced at the boundaries with NCEP/NCAR Reanalysis data and future simulations forced by the A2 emission scenario from the Finite Volume General Circulation Model (fvGCM) of NASA (Lin, 2004). Control runs will cover the 'standard' 30-year climatological period, namely 1961-1990. Future simulations cover the interval 2071-2100. As of the writing of this report, both 30-year simulations have beencompleted and analyses are in progress.

One of the striking issues that emerge from comparisons of observations (CRU TS 2.1 gridded 0.5 x 0.5 data set, Mitchell, 2004) with RegCM3 downscaling results is that the model overestimated precipitation, especially on the Black Sea and Eastern Adriatic Sea coasts (see Fig. 7). Though many trials with various 'physics' options have been made, this feature seems to be persistent. Besides this overestimation problem, general patterns of precipitation are well simulated in the control runs.



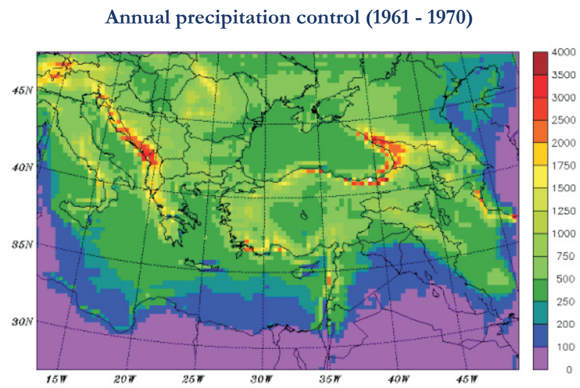
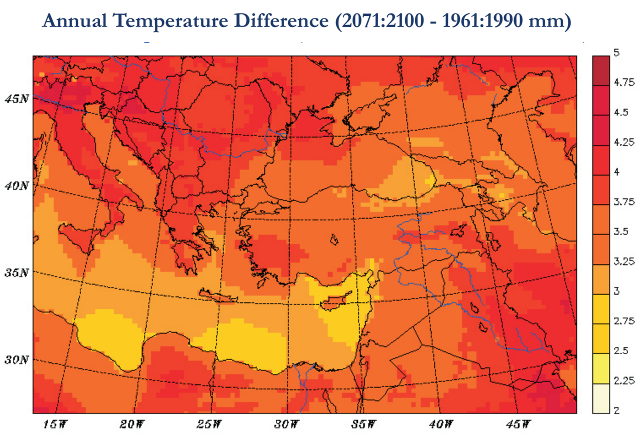


Figure.7 Comparison of observed and model simulated total annual precipitation.

Future simulations with RegCM3 are forced by the general circulation model fvGCM based on SRES A2 emission scenario. RegCM3 has been modified to take into account yearly variations in CO_2, CH_4, N2O, CFC11 and CFC12. The horizontal resolution is 30 km as stated above.

Some of the results of these simulations are displayed in Figs 9 and 10 as differences from the control run. When one focuses on Turkey, one can observe that in winter time, estimated temperature increase is higher in the eastern half of the country; in summer time this pattern is reversed and the western half of the country, especially the Aegean Region experiences temperature increases up to 6^0 C.



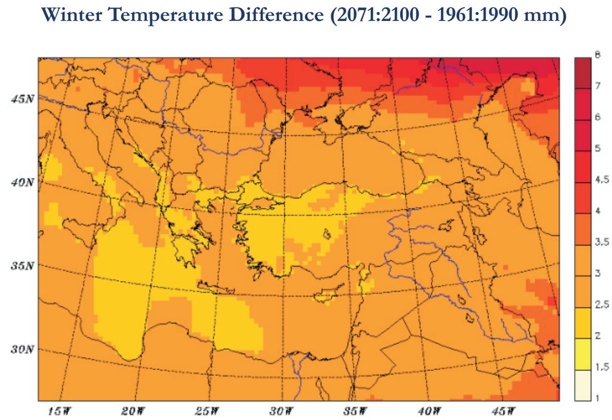
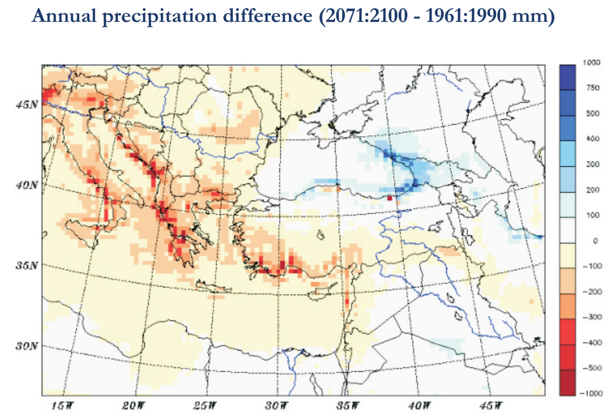


Figure.9 Differences in annual and winter temperatures between A2 run (2071-2100) and control run (1961-1990).



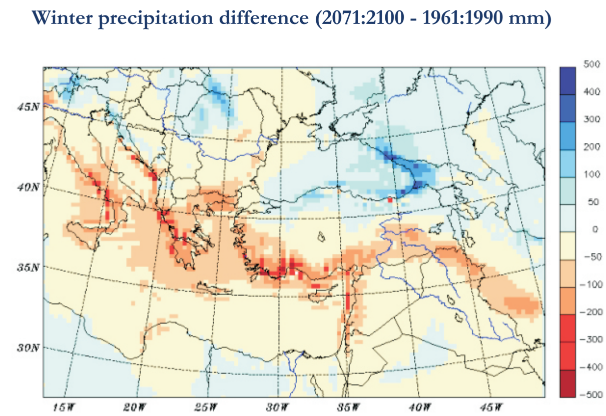


Figure.10 Differences in total annual and winter precipitation between A2 run (2071-2100) and control run (1961-1990).

Changes in precipitation are depicted on Fig. 10. In general, precipitation decreases along the Aegean and Mediterranean coasts and increases along the Black Sea coast of Turkey. Central Anatolia shows little or no change in precipitation. The most severe (absolute) reductions will be observed on the southwestern coast; in contrast, Caucasian coastal region is expected to receive substantially more precipitation. These observations are valid both for the annual and the winter totals.

Figure 11 illustrates the change in snow water equivalent. As seen from the figure the reduction is found to be up to 200 mm over the high plains of the eastern Anatolia and the eastern part of the Black Sea mountains. This means a reduction in the streamflow for the Euphrates-Tigris basin. Over the Eastern Mediterranean region several studies have been conducted on water resources due to its importance, but none of them has focused on the role of future climate change. Trans-boundary streams like Euphrates and Tigris rivers are the main sources of water for the region, not only for domestic and industrial use, but also for energy. During the last 30 years, several dams and irrigation systems have been constructed on the Euphrates-Tigris system that resulted in major land use changes. Therefore, results of this study may have important implications for water resources, and hence for energy generation and agricultural yield in the region.

Winter snow depth difference (A2 - Control)

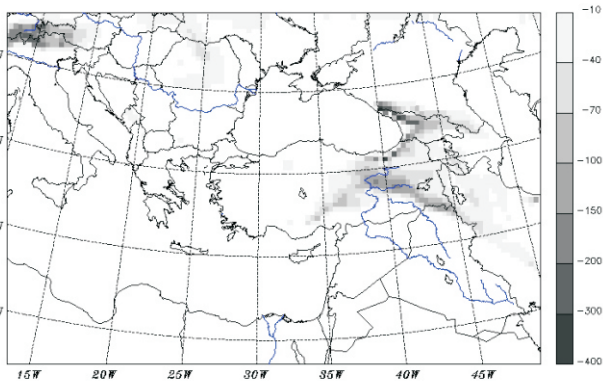


Figure. 11 Climate change projections for Turkey: changes in snow water equivalent (in mm) (Önol and Semazzi, 2006)

4.1.2 Studies Using MM5

MM5 is the principal tool for our downscaling studies. Though originally conceived for limited area, mesoscale weather forecasting tasks, it has been widely used for regional climate modelling purposes.

Current MM5 based simulation series is designed to involve three domain levels (see Fig. 12): a coarse (mother) domain (D01) with a horizontal resolution of 81 km is used, and there are 75, 60, 23 grid intervals in the East-West, North-South, and vertical directions, respectively. The second domain (D02) has a grid spacing of 27 km, and it covers entire Turkey and, nearby seas and countries. It consists of 118, 79, 23 grid intervals in the East-West, North-South, and vertical directions, respectively. However, the inner domain (D03 and D04) resolutions are chosen to be 9 km to capture more details, especially land use types of the area. While the third domain (D03) is located over the Marmara Region of Turkey with 46, 34, 23 grid intervals; the fourth domain (D04) is positioned over Eastern Turkey with 82, 58, 23 grid intervals in the East-West, North-South, and vertical directions, respectively. For the purpose of this study, all domains adopt the identical physics configuration.

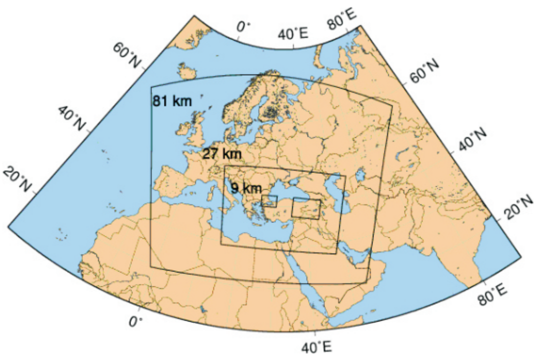


Figure.12 Simulation domains covered by MM5. Simulation of the climatological reference period 1961-1990 is still in progress.

4.2 Statistical Downscaling

Since late 1980's a wealth of studies addressed the problem of the statistical downscaling of coarse GCM simulation results to scales meaningful for impact studies. A wide variety of methodologies from the simplest linear regression schemes to sophisticated schemes involving artificial neural networks have been implemented (see for example, Tatlı et al., 2004 and Tatlı et al., 2005).

The essence of statistical downscaling is to first develop statistical models relating large-scale atmospheric fields to station-scale climate parameters, and later use these models to estimate the 'future' changes in these parameters using previously developed models. Evidently, this process involves decisions on:
'
(i) Large-scale' atmospheric fields to be used as predictors;
(ii) Station or 'small-scale' grid data for local climate parameters to be predicted (i.e. the predictands);
(iii) Mathematical framework for preprocessing of data and model structure.

For the period covered by this report, most of the effort has been put into the selection of appropriate methodologies that will be considered first for our statistical downscaling applications. At the present, we implement two such approaches:

Multiple Linear Regression (MLR):

The model based on multiple linear regression (von Storch and Zwiers, 1999) is used as a transfer function in order to construct a linear relationship between a dependent variable (predictand) and one or more independent variables (predictor).

Canonical Correlation Patterns (CCP):

Correlation between two univariate time series is expressed by Pearson's correlation coefficient. CCA is a method that can be used to correlate two multivariate time series. It may be understood by analogy to empirical orthogonal function (EOF) or principal component analysis.

EOF analysis tries to find patterns among the variates of a single multidimensional data set, where these patterns are supposed to account for most of the variance in the data. If the variates are time series, those patterns also have time coefficients (principal components, PCs hereafter) that show the strength of the pattern for each realisation in time. CCA, on the other hand, tries to find patterns in each of the two data sets, so that the correlation between time coefficients of the first pattern of the first data set, and the first pattern of the second data set, is the highest. The second highest correlation is supposed to be present between the second patterns of each data set, and so on. At the end, a few pair of patterns is found whose time coefficients are optimally correlated, that is, the pairs tend to occur simultaneously (Barnett and Preisendorfer, 1987; Xoplaki et al., 2002). One pair of patterns is called canonical correlation analysis pair (CCA pair hereafter). The time coefficients of patterns are formally called canonical correlation variates (CCVs). Canonical correlation coefficient is the Pearson's correlation coefficient between these CCVs. Canonical patterns are valuable not only for their synchronicity, they also represent a good deal of variance of the original data sets.

5. Sea Level Rise for Turkey

Much of the Turkish coast appears to experience sea-level changes within the generally accepted range of sea-level rise (1-2 mm/yr). The areas in which the rate of the sea-level rise has been less than 1-2 mm/yr (e.g. Samsun to Antalya) are assumed to have undergone tectonic uplift, whereas several of the larger river deltas have experienced sea-level rises substantially greater than the global rise. These areas are assumed to have undergone subsidence.

No systematic research has been conducted for the study of long-lasting trends in sea-level changes in Turkey. Sea-level measurements have been recorded in Turkey since 1974 whereas the most reliable series start in 1986 in Antalya of the Mediterranean Sea, Bodrum of the Aegean Sea, Erdek of the Marmara Sea and Samsun of the Black Sea coasts (Karaca, 2001).

Global sea-level rise for the last century has been estimated between 10 and 20 cm. For the Mediterranean, and Black Sea regions, sea-level rise is around 12cm in the last century. Although coastal cities cover less than 5% of the total surface area of Turkey, over 30 million people live in coastal areas.

More than 60% of the GNP in Turkey is produced in the coastal strip from Tekirdağ to Kocaeli, along the northern shoreline of the Marmara Sea (DPT, 2001). According to Karaca (2001) when the Common Methodology of the IPCC CZMS (1992) is applied to both Turkey and Istanbul province assuming 1-m ASLR scenario, Turkey lies in the class of low risk countries, but Istanbul has high risk values. The preliminary assessment of vulnerability analysis yields about 6% of its GNP for capital loss, and about 10% of its GNP for protection and adaptation costs of the country.

6. Future Work

RegCM3 based studies will continue and involve:

(i) Extensive analyses of base runs (1961-1990):
Model output will be compared to grid surface temperature and precipitation data (from CRU – Climatic Research Unit of University of East Anglia, UK) for the climatological reference period 1961-1990.
(ii) Extensive analyses of runs based on FVGCM A2 scenario:
Long term mean climate, interannual variability, atmospheric pattern indices (such as the NAO - North Atlantic Oscillation Index) will be thoroughly investigated.
A second set of runs based on the output of a different global climate model though model selection has not been finalised yet.

MM5 based studies are in development and will involve:

(i) Completion of base (1961-1990) reference runs for all domains;
(ii) Future climate simulations based on outputs from at least two global climate models

These simulations will be carried out for domains D1, D2, and a choice of D3-level domains. The choice will be made in coordination with teams working on impacts assessment in the areas of water resources, ecosystems, agriculture, etc.

We plan to continue to develop statistical models to connect large-scale features to local scale climate parameters and calibrate and verify these models with historical data. These models can then be applied to same global-scale climate model output that is used as boundary conditions to regional climate models for dynamical downscaling.

In this phase of the study, we plan to obtain change information regarding mean values of climate parameters, but efforts will also be made to develop models for extreme value statistics.

7. Acknowledgments

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MODELING FOR CLIMATE CHANGE EFFECTS IN THE GEDIZ AND BÜYÜK MENDERES RIVER BASINS

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1. Introduction

Hydrologic systems and water resources are likely to be seriously affected by global climate change and the purpose of this study is to provide preliminary assessment of such impacts for the Gediz and Büyükmenderes basins. Since precipitation and temperature are the major climatic inputs to a hydrologic system, the first part of the study covers investigations into changes that may be expected in these variables due to climate change. Two approaches are used for this purpose: (a) trend analysis are performed on observed precipitation, temperature and runoff data of selected hydro-meteorological stations in each basin; (b) for the same data set, various types of GCM (global climate models) are run to estimate likely changes in precipitation and temperature for two SRES (IPCC Special Report on Emission Scenarios) emission scenarios.

The second part of the study focuses on prediction of changes in hydrologic processes, i.e., evapotranspiration and runoff, that may result from estimated changes in precipitation and temperature. The steps of this analysis cover: (a) generation of climate change scenarios to estimate changes in precipitation and temperature for each basin; (b) application of these changes to the basins through a downscaling procedure and a basin water balance model to estimate changes in output variables of evapotranspiration and runoff; (c) testing of the sensitivity of runoff to changes in precipitation and temperature.

2. Description of Test Cases: Gediz and Büyük Menderes Basins

The case study focuses on two major and closely located river basins in western Anatolia along the Aegean Sea. The first is the Gediz River Basin, which is the second largest in the region with a total drainage area of about 18,000 km^2. The most significant feature of the Gediz Basin is water scarcity, which is due basically to competition for water among various uses, mainly irrigation with a total command area of 110,000 ha versus the domestic and fast growing industrial demand in the coastal zone; and to environmental pollution although the basin experiences droughts from time to time. Current analysis of the hydrologic budget of the basin indicates that the overall supply of water for various uses is almost equal to the overall demand. Practically, this means that there is no reserve for further water allocation in Gediz.

The second basin considered is that of Büyük Menderes, which is the longest river in the Aegean region. It meanders for 584 km through western Turkey before reaching the Aegean Sea with a large delta, consisting of several lagoons, extensive salt steppes and mudflats -- the biggest in Turkey. The Büyük Menderes Delta is an important wetland with an area of 9,800 ha; like the Gediz Delta, it is recognised as a RAMSAR site. Büyük Menderes has a total drainage area of 24,976 km^2, and the annual runoff is in the order of 3 km^3, which accounts for 1.6% of Turkey's water potential.

The basin is engineered into extensive water resource systems, including 13 dams and a large number of irrigation schemes. The total irrigated area in the basin is more than 88000 ha. The region is rich not only in terms of agriculture but also in industry, notably textiles and tourism. These activities indicate significant demand and competition

3. Trend Analysis

As a preliminary investigation of possible changes in climatic variables of the two basins, trend analyses are conducted to observed surface runoff series and selected precipitation and temperature time series at major stations. These analyses comprise testing of significant correlation between observed records versus time by using parametric (Pearson's r) and non-parametric (Spearman's rho) methods. Trend analyses are applied on observed data of selected meteorological (precipitation and runoff, see Table 1) and hydrologic (runoff, see Table 2) gauging stations. The locations are shown in Figure 2. For trend analyses of runoff series observed at streamgauging stations in the selected case basins, representative stations, which are free of the effects of upstream flow regulations, were selected to cover the entire watersheds.

Table.1 Selected meteorological stations.

	Station Name	Variable
Gediz Basin	Menemen	Daily Precipitation
	Manisa	Daily Precipitation
Büyük Menderes Basin	Uşak	Daily Precipitation
	Aydın	Monthly Precipitation
	Denizli	Monthly Precipitation

Table.2 Selected streamgaging stations.

Stations in Gediz Basin		Stations in Büyük Menderes Basin	
EIE509	EIE523	DSI714	EIE701
EIE514	EIE524	DSI730	EIE712
EIE515	EIE525	DSI737	EIE725
EIE522	EIE527	DSI771	EIE733

All precipitation series of the Gediz Basin show a significant downward trend over the period of records. Temperature series on the other hand, reflect significant upward trends. Thus, it is expected that the basin runoff will decrease over time since the main input of runoff decreases, and the major loss from runoff, or evapotranspiration increases with rising temperatures. This expectation is confirmed by the detection of statistically meaningful decreases in runoff series. In contrast, the precipitation records of the Büyük Menderes Basin do not show any statistically significant decrease despite the decreasing trends observed. The historical temperature series also indicate a negative slope for the regression line, even though the statistical tests reject the presence any significant trend. Despite the insignificant decreases in precipitation and temperature, the results of trend analyses on historical runoff series over the basin reveal statistically significant decreases.

The trend analyses of the runoff time series observed at a total of 16 stream gauging stations in the Gediz and Büyük Menderes Basins disclose statistically meaningful downward trends, that are likely to lead to serious water supply problems in the future. Thus, the possible effects of climate change at regional scale in each basin would be to amplify the existing scarcity and allocation problems. This in turn, will worsen current conflicts among water users, that are already observed as a result of intensive anthropogenic activity in both basins.

4. Generation of Climate Change Scenarios

Climate change effects in spatially averaged temperature and precipitation over Gediz and Büyük Menderes River Basins are assessed using a new version of the MAGICC/SCENGEN model, developed by NCAR-CRU (National Center for Atmospheric Research - Climatic Research Unit) using over a dozen recent GCMs. MAGICC/SCENGEN is a coupled gas-cycle/climate model (MAGICC) that drives a spatial climate change scenario generator (SCENGEN). MAGICC is a Simple Climate Model that computes the mean global surface air temperature and sea-level rise for particular emission scenarios for greenhouse gases and sulphur dioxide [1].

Figure.2 Locations of the selected meteorological and streamgaging stations.

The 49 emission scenarios involved in MAGICC model are investigated; and the ASF model of A2 and MESSAGE model of B2 storylines, which represent the marker scenarios of IPCC SRES, are selected to evaluate climate change effects in the case basins. On the other hand, there are 17 different GCM models in the SCENGEN package, which are run simultaneously to asses the total error between the generated and the observed values of temperature and precipitation. Next, to determine the best combinations of the GCMs, alternative model runs are performed, and the best combinations of the GCMs are selected as those which have minimum error terms for each variable (temperature and precipitation) and for each period (annual, seasonal and monthly). Then, these combinations are employed to generate changes in temperature and precipitation in the regions investigated.

In the next step, these global change scenarios are downscaled to the regional scale by using SCENGEN. In the regional analysis, the changes in the temperature and precipitation are examined on annual, seasonal (four seasons) and monthly (12 months) basis. The procedure is repeated for both emission scenarios, i.e., A2-ASF and B2-MESSAGE and for three projection years; 2030, 2050 and 2100. The IPCC SRES B2 scenario assumes a world of moderate population growth and intermediate level of economic development and technological change. SCENGEN estimates a global mean temperature increase of 0.85 °C by 2030, 1.33 °C by 2050, and 2.48 °C by 2100. The IPCC SRES A2 scenario assumes a world of high population growth and intermediate level of economic development and technological change. SCENGEN estimates a global mean temperature increase of 0.67 °C by 2030, 1.29 °C by 2050, and 3.47 °C by 2100. The estimated changes in temperature and precipitation are summarized in Tables 3 through 6.

According to results from scenarios B2-MESSAGE and A2-ASF, an increase of 1.2°C in mean annual temperature, and a decrease of 5% in mean annual precipitation can be expected for 2030. In 2050, the mean annual temperature increases by around 2°C, and mean annual precipitation decreases by approximately 10%. On the other hand, due to the assumptions of the applied GCMs, in 2100, the range of temperature and precipitation estimates exhibits a steep deviation compared to previous estimates, so that any interpretation on the estimated values for this year would be risky. In the context of model estimations, increase in monthly temperatures indicate that warmer winters are expected, while summers get hotter. Although decreases are expected in precipitation in all months, the sharp decreases in spring and autumn are significantly important, because summers in the region are already dry.

5. Assesment of the Impact of Climate Change on Hydrology and Water Resources

Global warming due to the greenhouse effect is expected to cause changes in meteorological conditions [4]. Generally, climate change or its increased variability is expected to alter the timing and the magnitudes of such processes as precipitation, evapotranspiration and runoff. As a result, regions where floods are rare may encounter more frequent events of high flows, while droughts and water scarcity may intensify in other regions [5, 6]. Thus, the need is indicated to evaluate the impact of expected climate change on hydrology and water resources at regional and local levels by the use of GCM and hydrologic models [7].

Table.3 Generated Changes in Temperature under the IPCC B2-MES Scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modelled							
	Mean	Mean	Std. Dev.	Change	Change in Variance	Change	Change in Variance	Change	Change in Variance
	1	2	3	4	5	6	7	8	9
	°C	°C	°C	°C	%	°C	%	°C	%
Annual	16.3	16.4	0.4	1.2	5.1	1.8	7.9	3.2	14.7
DJF	9.4	9.4	0.8	1.0	-2.5	1.5	-3.9	2.6	-7.2
MAM	14.4	14.4	0.6	1.1	2.7	1.7	4.1	2.9	7.7
JJA	23.4	23.5	0.6	1.6	3.8	2.4	5.9	4.1	10.9
SON	17.8	17.8	0.8	1.4	-2.0	2.0	-3.1	3.6	-5.7
January	8.7	9.0	1.4	0.9	1.1	1.4	1.7	2.5	3.1
February	9.2	9.3	1.2	0.9	5.6	1.3	8.8	2.4	16.4
March	10.9	10.9	1.0	0.8	-4.6	1.2	-7.2	2.1	-13.4
April	14.2	14.3	0.8	1.1	0.6	1.6	0.9	2.7	1.8
May	18.0	17.9	0.9	1.4	7.1	2.1	11	3.7	20.5
June	21.8	21.9	1.1	1.6	5.1	2.3	7.9	4.1	14.8
July	24.1	23.9	0.8	1.6	-0.5	2.3	-0.7	4.1	-1.3
August	24.4	24.4	0.8	1.7	-1.1	2.6	-1.6	4.5	-3.1
September	21.7	21.6	0.8	1.5	1.5	2.2	2.3	3.8	4.3
October	17.8	17.8	1.1	1.4	2.5	2.1	3.9	3.7	7.3
November	14.0	13.8	1.1	1.1	0.4	1.6	0.6	2.7	1.1
December	10.4	10.5	1.3	1.0	-3.2	1.5	-4.9	2.6	-9.2

Column 1: Obs.Base. This is observed climate for the base period. SCENGEN uses the globally complete CMAP [2] precipitation and CRU [3] temperature climatologies.
Column 2: Mod.Base: The model simulation of 1990 climate (base).
Column 3: S.D.Base: Standard deviation (interannual variability) of the present-day climate as simulated by the selected GCM/GCMs..
Column 4-6 and 8: Change: Change in variable for the time period selected relative to 1990. This could be added to the observed climate data to produce the downscaled climate scenario.
Column 5-7 and 9: S.D.Change: Percentage change in standard deviation of the selected climate variable simulated by the GCMs.

In this section, selected GCM scenarios of the previous step are analyzed at regional scales by means of a parametric water budget simulation model to observe the effects of temperature and precipitation changes on runoff in the Gediz and Büyük Menderes river basins. The model, based on the modified Thornthwaite water balance model, operates on a monthly basis with precipitation (P) and potential evapotranspiration (PET) as input variables. Model parameters to be calibrated are: maximum soil moisture SMAX (mm), watershed lag coefficient SSRC, groundwater reservoir coefficient GWRC, and storm runoff coefficient SRC. The output variables are modelled runoff Q (mm) and soil moisture S (mm). In this model, potential evapotranspiration (PET) is defined as an exponential function ($PET=Ae^{Bt}$) of temperature, using two parameters A and B.

For each month, the model computes potential evapotranspiration (PET) as a function of temperature. The portion SRC x P is distinguished from P as fast surface runoff, and the potential evapotranspiration is compared to P-(SRC x P). If this quantity is not sufficient to fulfill potential evapotranspiration, then water is drawn from the soil moisture of the previous month, and the moisture of the current month is decreased. If adequate water exists in soil storage to exceed the maximum holding capacity (SMAX), the surplus water is diverted to the river by the parameter SSRC.

Table .4 Generated changes in temperature under the IPCC A2-ASF scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modelled							
	Mean	Mean	Std.	Change	Ch. in Var.	Change	Ch. in Var.	Change	Ch. in Var.
	1	2	3	4	5	6	7	8	9
	°C	°C	°C	°C	%	°C	%	°C	%
Annual	16.3	16.4	0.4	1.2	4.0	2.0	7.7	4.4	20.6
DJF	9.4	9.4	0.8	1.0	-2.0	1.6	-3.8	3.5	-10.1
MAM	14.4	14.4	0.6	1.2	2.1	1.9	4.0	4.1	10.8
JJA	23.4	23.5	0.6	1.5	3.0	2.5	5.7	5.5	15.3
SON	17.8	17.8	0.8	1.2	-1.6	2.0	-3.0	4.7	-8.0
January	8.7	9.0	1.4	1.0	0.8	1.6	1.6	3.6	4.3
February	9.2	9.3	1.2	0.7	4.4	1.2	8.6	3.1	22.9
March	10.9	10.9	1.0	1.0	-3.6	1.6	-7.0	3.1	-18.8
April	14.2	14.3	0.8	1.2	0.5	1.9	0.9	3.7	2.5
May	18.0	17.9	0.9	1.3	5.6	2.2	10.7	5.0	28.7
June	21.8	21.9	1.1	1.5	4.0	2.5	7.7	5.5	20.7
July	24.1	23.9	0.8	1.5	-0.4	2.4	-0.7	5.4	-1.9
August	24.4	24.4	0.8	1.6	-0.8	2.7	-1.6	6.0	-4.3
September	21.7	21.6	0.8	1.2	1.2	2.1	2.3	5.1	6.1
October	17.8	17.8	1.1	1.3	2.0	2.1	3.8	4.9	10.2
November	14.0	13.8	1.1	0.9	0.3	1.5	0.6	3.5	1.5
December	10.4	10.5	1.3	1.2	-2.5	1.9	-4.8	3.5	-12.9

The remaining part is routed to groundwater storage. The groundwater portion of the runoff is fed by groundwater storage of the previous month, using GWRC. Then, the surface runoff of the ith month is computed as follows:

$$Q_i = SRC.P_i + SSRC.SSW_i + GWRC.GW_{i-1} \quad (1)$$

where, SRC is the surface runoff coefficient; P_i, precipitation in i^{th} month (mm); SSRC, subsurface runoff coefficient; SSW_i, exceeded part of subsurface storage in ith month (mm); GWRC, groundwater runoff coefficient; and GW_{i-1}, groundwater storage in ith month (mm).

The calibration of the model is based on the correlation between observed and modelled runoff values. The mean values of the modelled runoff series are also considered to test model fitness. The verified model parameters are used in the climate change scenarios for the years 2030, 2050 and 2100. As the runoff in the two basins are extensively controlled by several large and small dams for both hydropower and irrigation water supply purposes, there are only a few flow stations which are free of the effects of flow regulations. Thus, only the EIE509 (902 km^2) on Medar tributary of Gediz and EIE701 (948 km^2) on Çine tributary of Büyük Menderes are used as the representative stations for model applications.

Table.5 Generated changes in precipitation under the IPCC B2-MES scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modelled							
	Mean	Mean	Std.	Change	Ch. in Var.	Change	Ch. in Var.	Change	Ch. in Var.
	1	2	3	4	5	6	7	8	9
	mm/day	mm/day	mm/day	%	%	%	%	%	%
Annual	1.7	1.7	0.2	-5.0	5.6	-8.0	8.7	-15.4	16.2
DJF	3.3	3.1	0.7	-2.7	-2.6	-4.7	-4.0	-10.2	-7.5
MAM	1.7	1.6	0.4	-5.1	-1.9	-7.9	-3.0	-14.4	-5.6
JJA	0.3	0.3	0.1	-26.1	-5.5	-36.8	-8.5	-59.9	-15.9
SON	1.5	1.5	0.4	-9.0	-1.6	-14.5	-2.5	-28.1	-4.6
January	3.2	3.2	1.1	-3.3	8.9	-5.5	13.8	-11.6	25.8
February	2.9	2.7	1.1	-0.7	-14.2	-2.6	-22.0	-7.9	-41.1
March	2.4	2.2	0.9	-0.2	-3.2	-0.1	-4.9	-0.6	-9.2
April	1.5	1.5	0.5	-5.9	13.6	-9.3	21.1	-16.2	39.5
May	1.0	1.0	0.4	-12.4	-10.0	-18.7	-15.6	-31.6	-29.2
June	0.5	0.5	0.3	-24.9	-0.6	-35.9	-1.0	-59.3	-1.8
July	0.3	0.3	0.2	-35.2	-9.3	-47.6	-14.5	-73.0	-27.0
August	0.2	0.2	0.1	-13.5	-16.1	-20.4	-25.1	-37.2	-46.8
September	0.4	0.4	0.3	-9.9	-6.8	-15.7	-10.6	-30.1	-19.8
October	1.3	1.3	0.8	-17.1	-10.5	-26.5	-16.3	-48.5	-30.4
November	2.9	2.8	1.0	-6.2	1.2	-10.5	1.9	-21.6	3.5
December	3.8	3.5	1.2	-4.4	3.2	-6.5	5.0	-12.1	9.3

Table.6 Generated changes in precipitation under the IPCC A2-ASF scenario.

Period	Baseline			2030		2050		2100	
	Observed	Modelled							
	Mean	Mean	Std.	Change	Ch. in Var.	Change	Ch. in Var.	Change	Ch. in Var.
	1	2	3	4	5	6	7	8	9
	mm/day	mm/day	mm/day	%	%	%	%	%	%
Annual	1.7	1.7	0.2	-5.8	4.4	-10.2	8.5	-23.8	22.7
DJF	3.3	3.1	0.7	-5.6	-2.0	-9.2	-3.9	-19.0	-10.5
MAM	1.7	1.6	0.4	-7.4	-1.5	-11.5	-2.9	-21.9	-7.8
JJA	0.3	0.3	0.1	-15.5	-4.3	-26.4	-8.3	-66.3	-22.3
SON	1.5	1.5	0.4	-4.8	-1.3	-11.9	-2.4	-39.6	-6.5
January	3.2	3.2	1.1	-7.8	7.0	-11.9	13.5	-22.0	36.1
February	2.9	2.7	1.1	-1.2	-11.2	-4.5	-21.5	-16.3	-57.6
March	2.4	2.2	0.9	-9.9	-2.5	-11.6	-4.8	-8.4	-12.8
April	1.5	1.5	0.5	0.3	10.7	-3.1	20.6	-17.4	55.2
May	1.0	1.0	0.4	0.0	-7.9	-5.9	-15.3	-32.0	-40.8
June	0.5	0.5	0.3	-1.1	-0.5	-10.4	-1.0	-57.5	-2.6
July	0.3	0.3	0.2	-3.7	-7.3	-11.5	-14.1	-59.7	-37.8
August	0.2	0.2	0.1	-19.2	-12.7	-29.5	-24.5	-56.8	-65.5
September	0.4	0.4	0.3	-6.9	-5.4	-14.5	-10.3	-42.9	-27.7
October	1.3	1.3	0.8	-1.8	-8.2	-11.7	-15.9	-58.1	-42.6
November	2.9	2.8	1.0	-6.1	1.0	-12.6	1.8	-34.5	4.9
December	3.8	3.5	1.2	-7.2	2.5	-10.6	4.9	-19.3	13.0

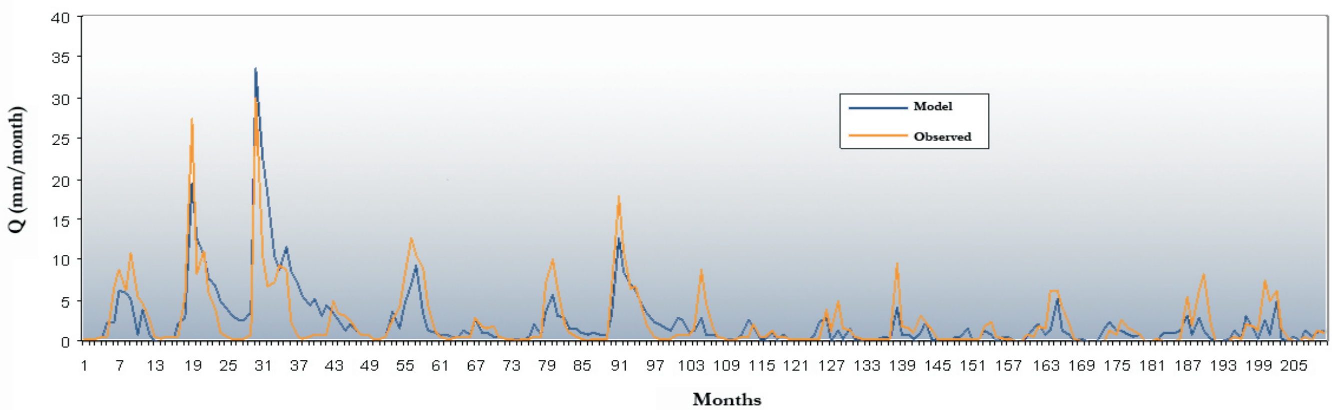

Figure.3 Observed and modeled runoff series of EIE509 in Gediz Basin (for 1980-1996 verification periods).

For simulation of EIE509 flows, precipitation and temperature records of Akhisar meteorological station in the Gediz Basin are used, while the records of Yatağan Meteorological Station are used for station EIE701 in the Büyük Menderes Basin. The calibration of EIE509 and EIE701 flows is carried out with observed runoff series of 1962-1979 and 1990-1995, respectively. Calibrated parameters are verified for the periods 1980-1996 and 1996-2000, respectively for the two stations.

Table 7. Calibration and verification criteria for EIE509 station.

EIE509	Calibration		Verification	
	Model	Observed	Model	Observed
Mean	4.0 mm/month	4.1 mm/month	2.2 mm/month	2.5 mm/month
Correlation	0.76		0.78	

EIE701	Calibration		Verification	
	Model	Observed	Model	Observed
Mean	2.3 mm/month	2.6 mm/month	6.1 mm/month	5.4 mm/month
Correlation	0.78		0.80	

As an example, Figure 3 shows the verification of both the observed and the modelled runoff for EIE509. Table 7 gives the calibration and verification criteria for both stations.

In the next step, sensitivity analysis is carried out by running the water budget model under the climate change scenarios to determine the variations in runoff due to predicted changes in precipitation and temperature. This study is carried out only for the station EIE509 in the Gediz Basin since it has a sufficiently long data records. Table 8 presents the results of this study as changes in runoff versus the hypothetical changes in precipitation and temperature. Basically, it is determined that any decrease in the basin runoff is sensitive to (a) increasing temperature in the order of 11% - 20%; (b) decreasing precipitation, in the order of 21% - 38%; and (c) both factors in the order of 29% - 52%.

In the last step of the modeling study, the water budget model is operated under the scenarios (IPCC SRES A2 and B2) of 2030, 2050 and 2100 climate conditions. The changes in runoff caused by decreases in precipitation and increases in temperature under the climate change scenarios B2 and A2 are presented in Table 9. Simulation results of the water budget model based on the prescribed climate change scenarios show that nearly 20% of the surface waters will be reduced by the year of 2030. By the years 2050 and 2100, this amount will rise to nearly 35% and more than 50%, respectively. The decreasing surface water potential of the basins will cause serious water stress problems among water users, mainly being agricultural, domestic and industrial water users.

Expected changes in water demand of crops specific for the region studied are also evaluated with respect to the climate change scenarios of B2 and A2. Monthly potential evapotranspiration (PET) values of the selected crops are computed, using the Blaney-Criddle formula, which is the common method employed by the State Hydraulic Works (DSI) of Turkey in irrigation planning. According to the climate change scenarios of B2 and A2, the PET and crop water demands increase dramatically for the year 2100. Although the increases in PET are approximately 10%, 15% and 30% for the years 2030, 2050 and 2100, respectively, changes in water demand are higher than those in PET due to decreases in estimated rainfall, namely, the effective rainfall in the climate change scenarios (Table 10). Thus, while crops demand more water than usual, the climate-induced reduction in rainfall values creates an additional impact so that the crop water demand increases dramatically.

Table.8 The runoff variations versus the change in precipitation and temperature.

?Q (%)		?P -10%	-5%	0%	+5%	+10%
?t	+2	-52	-37	-20	-1	22
	+1	-46	-29	-11	11	36
	0	-38	-21	0	24	52
	-1	-31	-12	12	37	70
	-2	-23	-1	23	54	88

Table.9 The runoff changes under the climate conditions in 2030, 2050 and 2100 in Gediz and Buyuk Menderes River Basins.

	2030		2050		2100	
	B2	A2	B2	A2	B2	A2
EIE509 Gediz Basin	-%23	-%32	-%35	-%48	-%58	-%71
EIE701 B. Menderes Basin	-%10	-%21	-%20	-%38	-%45	-%71

Table.10 The average percentage change (increase) in potential evapotranspiration (PET) and crop water demand at selected meteorological stations in the region studied.

	2030				2050				2100			
	B2		A2		B2		A2		B2		A2	
GEDIZ	PET	Demand	PET	Demand	PET	Demand	PET	Demand	PET	Demand	PET	Demand
Menemen	12%	13%	10%	11%	16%	20%	17%	19%	27%	36%	36%	47%
Manisa	10%	14%	9%	11%	15%	20%	15%	19%	26%	37%	35%	48%
B.MENDERES												
Denizli	11%	16%	8%	12%	15%	23%	16%	21%	26%	42%	35%	54%
Nazilli	10%	12%	9%	10%	14%	18%	15%	18%	24%	33%	33%	44%

6. Conclusion

The present study shows that the trend analyses on the runoff series in the Gediz and Büyük Menderes Basins reveal significant decreases over the entire period of runoff records between the years 1960 and 2000. Consequently, it may be stated that the effects of an expected climate change at regional scale in each basin would be to intensify the already existing water scarcity and water allocation problems. This, in turn, will magnify current conflicts among water users, which have already started due to the intense anthropogenic activity in both basins.

Future projections of the climate considering different emission scenarios over the basins are also evaluated by GCMs. According to the results of B2-MESSAGE and A2-ASF, monthly temperatures increase that indicate warmer winters is expected, while summers get hotter. Although there are decreases in precipitation in all months regarding the model outcomes, the sharp decreases in spring and autumn are significantly important, because the summer seasons in the region are already dry. Simulation results of the water budget model have shown that the surface water potential of the test basins will decrease to cause serious water stress problems among water users. Furthermore, the increasing potential crop evapotranspiration will increase the irrigation water demand enormously.

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EFFECTS OF CLIMATE CHANGE ON THE ECOSYSTEM OF BÜYÜK MENDERES

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1. Introduction

The benthic macroinvertebrate assemblages broadly reflect environmental conditions and are used as indicators of environmental degradation and restoration. Multivariate methods permit considerable understanding of the community structure and relationships with corresponding environmental properties.

Benthic macroinvertebrate assemblage and physicochemical data was assessed for 17 sites in the Büyük Menderes River in Southwestern Turkey for one-year period between 1998 and 1999. Relationships between macroinvertebrate assemblages and environmental variables were explored by canonical correspondence analysis. This is a first attempt to provide a detailed ecological survey of benthic macroinvertebrate taxa and water quality relationships; providing a framework for understanding climate change on the Büyük Menderes River ecosystem and biodiversity.

2. Method

225 species of benthic macroinvertebrates were identified. The distribution of the species is influenced significantly by environmental variables. Environmental variables affecting taxa distribution, according to CCA were: nitrite, nitrate, chloride, orthophosphate, electrical conductivity, dissolved oxygen, ammonium, total alkalinity, altitude, temperature, velocity, drainage area, and stream order (Fig. 1). The research area, Büyük Menderes River, is an important river system which includes wetland areas of the eastern Mediterranean region such as Lake Bafa. Büyük Menderes arises as springs in the limestone formations near Dinar and flows westerly for about 560 km, draining 24.000 km^2 of southwestern Turkey before joining the Aegean Sea at Bafa Lake and the Büyük Menderes Delta, 115 km south of İzmir.

3. Results and Disscussion

The aim of this research was to determine the composition of benthic macroinvertebrates and the relationships between their distribution and environmental quality characteristics of the Büyük Menderes River and identify possible effects of climate change on benthic macroinvertebrte assemblages. Relationships between macroinvertebrate assemblages and environmental variables were explored by canonical correspondence analysis via a model of distribution of taxa and the effect of climate change on macroinvertebrate taxa in the ecosystem. According to "Climate Change Scenarios for Turkey: Preliminary Studies" by Nüzhet Dalfes, Mehmet Karaca and Ömer Lütfi Şen,

(i) Streamflow has significant decreasing trends in the western and southwestern parts of Turkey. This applies, more or less, to all seasons.

(ii) Average annual temperatures show significant upward trends in the western and the southern parts of Turkey in summer.

Increases in water temperatures as a result of climate change will affect ecological processes, the geographic distribution of aquatic species, causing the extinction of species and loss of biodiversity. Climate change will alter hydrologic characteristics and water quality of running waters and will affect species composition and ecosystem functions. Climate change effects on benthic macroinvertebrate taxa is given as:

3.1. The Taxa Prefer Low Temperature, High Dissolved Oxygen, High Current Velocity (Table.1): Taeniopterygidae, Nemouridae, Leuctridae from Plecoptera; Oligoneuriidae, Heptageniidae, Ephemerellidaefrom Ephemeroptera; Aeshnidae, Gomphidae from Odonata; Rhyacophilidae, Leptoceridae and some species of Hydropsychidae from Trichoptera; Gerridae, Notonectidae from Hemiptera; Elmidae from Coleoptera; Pyraustidae from Lepidoptera; Tipulidae, Athericidae from Diptera. They are not tolerant to climate change effects (high temperature, low dissolved oxygen, low water velocity) on running water ecosystems according to CCA figure.

Table.1 Macroinvertebrate taxa in CCA analysis (Groups A and B)

Grup A	Grup B
Taeniopterygidae	Planorbidae
Nemouridae	Tubificidae
Leuctridae	Naididae
Oligoneuriidae	Glossiphoniidae
Heptageniidae	Calopterygidae
Ephemerellidae	Sciomyzidae
Aeshnidae	Gerridae
Gomphidae	Notonectidae
Rhyacophilidae	Muscidae
Hydropsychidae	Chrysomelidae
Leptoceridae	
Elmidae	
Athericidae	
Pyraustidae	
Tipuliidae	

3.2. The taxa can tolerate high temperature, low dissolved oxygen, low current velocity (Table. 2): Valvatidae, Bithyniidae, Planorbidae from Gastropoda; Unionidae, Sphaeriidae from Lamellibranchiata; Coenagrionidae from Odonata; Dytiscidae from Coleoptera; Lumbricidae, Tubuficidae, Naididaefrom Oligochaeta; Glossiphoniidaefrom Hirudinea; Platycnemididae, Calopterygidae from Odonata; Dytiscidae from Coleoptera; Sciomyzidae, Muscidae, Chironomidae from Diptera. They can tolerate high temperature (Fig. 1) and climate change effects on the Büyük Menderes ecosystem.

Table.2 Macroinvertebrate taxa in CCA analysis (Groups A and B)

Grup C	Grup D
Valvatidae	Planorbidae
Bithynidae	Sphaeriidae
Unionidae	Lumbricidae
Coenagrionidae	Glossiphoniidae
Dytiscidae	Platycnemididae
	Dytiscidae
	Limoniidae
	Chironomidae

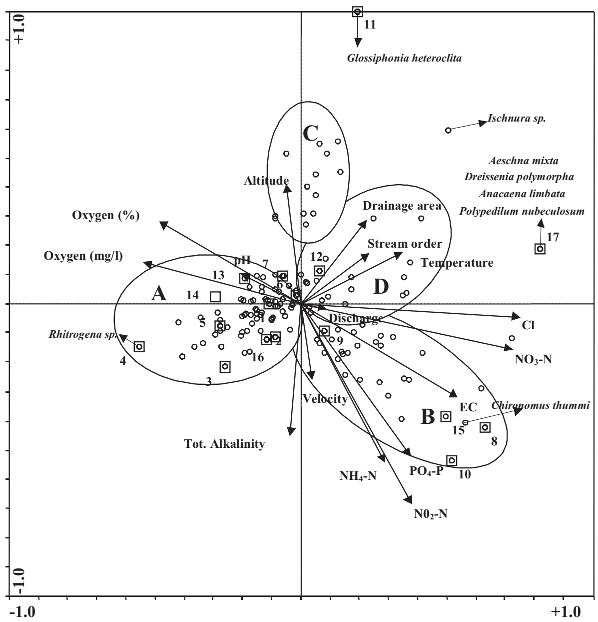

Figure.1 CCA diagram for Büyük Menderes. Environmental variables are indicated by arrows; benthic macroinvertebrate taxa are indicated by circles.

CORRELATION BETWEEN TEMPERATURE, RAINFALL AND LEPTOSPIROSIS INCIDENCE IN İSTANBUL-TURKEY

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Introduction

Climatic changes and their association with increasing incidence of various infectious diseases have been investigated previously (2, 3, 4). Temperature and rainfall may have synergistic effects on leptosira transmission (5). Leptospira are distributed worldwide and infect many types of domestic and wild animals. Humans become incidental, "dead-end" hosts because transmission from humans to animals does not occur. Rats have been classically associated with this disease, but sheep, cattle, dogs and other domestic animals may also be infected. In the wild, foxes, raccoons, skunks, shrews and hedgehogs also carry leptospires (5-8).

This study aims at providing preliminary assessments regarding the possible impacts of global climate change on the force of leptospira transmission. Transmission is likely to be seriously affected by global climate change (5-18). Organisms such as pathogenic leptospires can survive for from several days to months in soil, mud and fresh water with a pH in the neutral range, and in the internal organs of animals. Epidemiologic factors associated with leptospirosis include the collection of rainwater for household use, contact with cattle and cattle urine, or handling animal tissues. Infection usually results from direct or indirect exposure to the urine of a leptospiruric animal. Indirect exposure through contaminated water, mud and soil accounts for most sporadic cases, common-source outbreaks in swimmers, and cases in occupational groups such as rice farmers, sugar cane workers, sewage workers and military personnel (5- 11).

We performed active screening for leptospirosis in İstanbul over six months of 2006 (from January to June) as a pilot study. The objective was to determine endemicity potential of leptospirosis in İstanbul. This would permit the determination of climatic and environmental factors, as well as rainfall, that are probably responsible for leptospirosis.

If a relationship can be established, future epidemics of leptospirosis can be anticipated by studying daily temperature and rainfall patterns.

Materials And Methodology

Patients were screened at the İstanbul University Medical Faculty Hospital, Cerrahpaşa Medical Faculty Hospital, the Department of Infectious Diseases and Emergency Care Unit at the Gülhane Military Medical Academy, the Haydarpaşa Training Hospital, Marmara University Medical Faculty Hospital and other hospitals in İstanbul.

A diagnosis of leptospirosis and follow-up form were used for the determination of probable leptospirosis cases. A standardised data entry form was used to document demographic and epidemiological data (age, sex, occupation, address, history of exposure to heavy rain, contact with contaminated flood waters or creeks etc). Detailed medical history was taken and the patient's clinical progress was monitored daily.

The data for analysis were obtained from two main sources:

1. The data include the number of leptospirosis cases in İstanbul on a regional basis.

2. The Research Unit at the Turkish State Meteorological Service provided the climatic data, mainly including temperature and rainfall changes over time (days/week/months/years) in the İstanbul area. The times and duration of severe rainfall were also documented. Average monthly temperature and rainfall, together with the total amount of rainfall, were obtained from the State Meteorological Directorate. The data was evaluated with regard to new leptospirosis cases.

Diagnostic criteria and case classification

A case was defined as "suspected leptospirosis" in the presence of acute high fever (>38.5 °C) and multiorgan involvement (at least two organs in the hepatic, renal/urinary, musculoskeletal, pulmonary, central nervous, or cardiac systems) findings. A case was defined as "probable leptospirosis" in the presence of at least three of the six cardinal symptoms and clinical findings and also of at least three of the six important laboratory findings regarding the disease. Cardinal symptoms and findings of leptospirosis were assessed as; (i) high fever, (ii) periorbital/frontal headache, (iii) myalgia/ abdominal pain/ lumbar pain, (iv) conjunctival hyperemia, (v) chills/ flu-like illness, and (vi) fatigue.
Important laboratory findings of the disease were assessed as; (i) leukocytosis (>10 000/mm^3)/ neutrophilia, (ii) increased ALT/ AST, (iii) increased CPK/ LDH, (iv) thrombocytopenia, (v) increased urea/ creatinine, (vi) urine abnormalities. A case in the probable leptospirosis group was defined as "confirmed leptospirosis " when one of the specific leptospirosis laboratory tests (LC, ELISA Ig M) resulted positive.

Findings

During the study period (January-June 2006), leptospirosis was determined in 78 cases. Monthly and yearly average rainfall and temperature data (from January, 2004 to June, 2006) were provided by the State Meteorological Service and analysed for the frequency of leptospirosis cases. Numbers of leptospirosis cases that confirmed as laboratory (from January of 2004 to 2006) were obtained from the Cerrahpaşa Medical Faculty Hospital- Clinical Microbiology Department.

Table.1 Yearly temperature distribution in the first six months of the last three years in İstanbul

Months- Years	January	February	March	April	May	June
2004	5,3	5,9	8,4	12,2	16,4	21,4
2005	7,1	6,1	7,5	12,4	16,4	20,6
2006	4,4	5,8	8,6	12,3	16,6	21.7

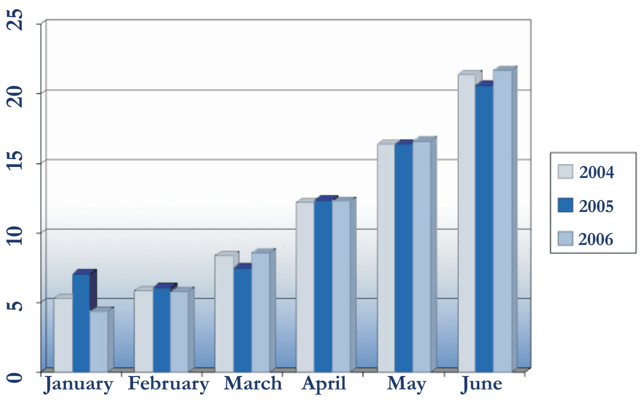

Figure.1 Yearly temperature distribution in the first six months of the last three years in Istanbul.

Table.1 reveals that there was no difference between the average temperatures in January and February of 2004-2005 and 2006. In March, however, there was a 2.3 °C increase in temperature compared to January and February. Compared to January and February, the temperature increased by 2.1 °C in March, with a 4 °C rise in the months following March (April, May and June).

Table.2 Yearly distribution of rainfall in the first six months of the year in İstanbul

Months-years	January	February	March	April	May	June
2004	158,5	40,6	59,7	21,6	37.7	28.8
2005	139,6	134,5	44,7	18,1	17,3	26,2
2006	103,7	106,3	93,0	21,1	24,7	25,2

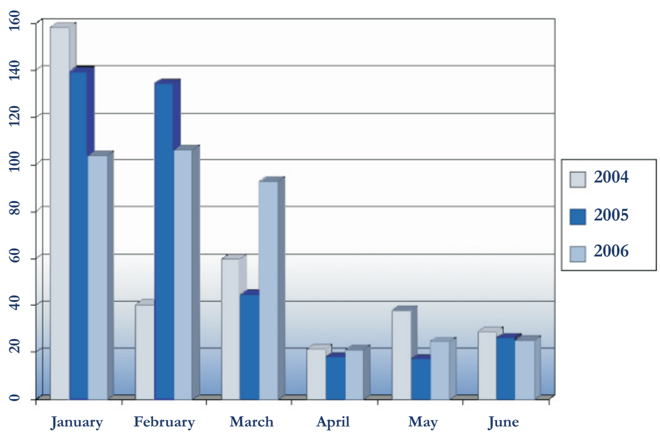

Figure.2 Yearly distribution of rainfall in the first six months of the year in İstanbul

Monthly and yearly average rainfall and temperature data were provided by the State Meteorology Service General Manager Electronic Data Manager Göztepe/İstanbul, Station no: 17062

Table.2 and figures (1-6) show that in January and February rainfall levels were 100% higher compared to March and 400% higher compared to April, May and June in 2004-2005 and 2006. The numbers of leptospirosis patients in January and February and March 2004-2005 and 2006 were broadly similar, but in April we observed an increase of 50% compared to January, February and March.

In terms of total patient numbers in 2004-2005 and 2006, the following increases were observed: January 16.69%, February 19.71%, March 18.98 %, April 44.53%, May 54.23% and June 69.14%. The total number of leptospirosis patients in April, May and June increased considerably, $X^2=3.9$, $P<0.001$, compared to January, February and March.

Table.3 Yearly and monthly distribution of leptospirosis cases in Istanbul in the last three years

Date	January	February	March	April	May	June	Total
2004	12	12	10	30	22	27	113
2005	5	8	8	16	18	19	78
2006	6	7	8	15	19	23	78
Total	23	27	26	61	59	69	137

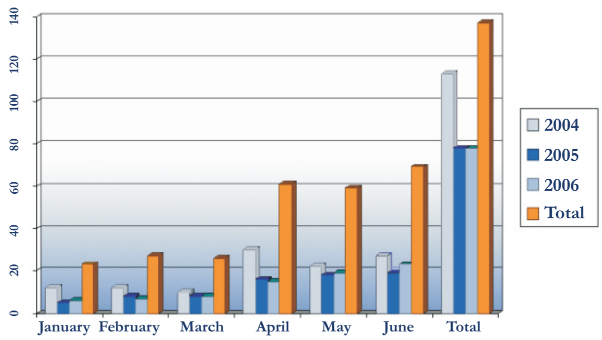

Figure.3 Yearly and monthly distribution of leptospirosis cases in Istanbul in the last three years

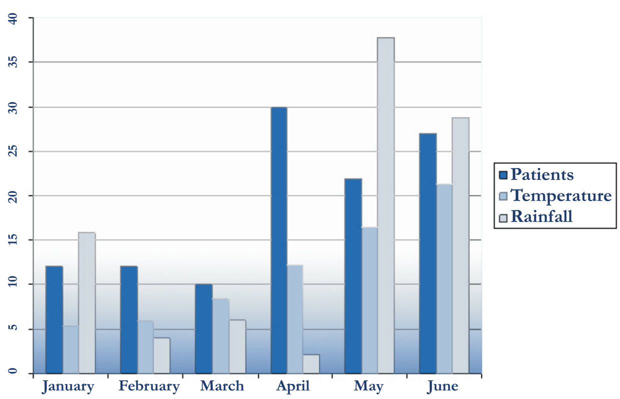

Figure.4 Monthly distribution of leptospirosis cases, temperature and rainfall in Istanbul , year of 2004

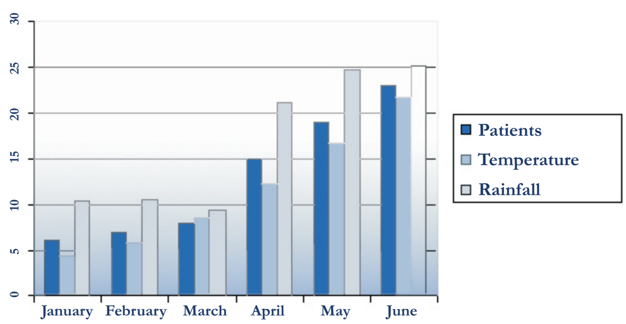

Figure.5 Monthly distribution of leptospirosis cases, average temperature and rainfall in Istanbul, year of 2005

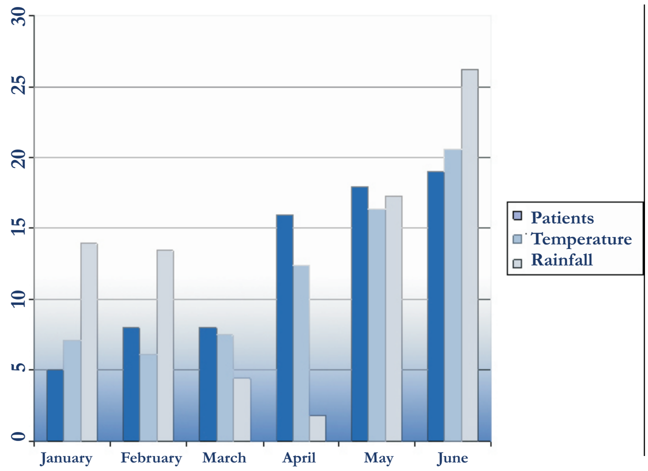

Figure.6 Monthly distribution of leptospirosis cases, average temperature and rainfall in İstanbul , year of 2006

Discussion

Climatic factors influence the emergence and reemergence of infectious diseases, in addition to multiple human, biological, and ecological determinants. Climate change would directly affect disease transmission by shifting the vector's geographic range and increasing reproductive and biting rates and by shortening the pathogen incubation period. Climate-related increases in sea surface temperature and sea level can lead to higher incidence of water-borne infectious illnesses. Human migration and damage to health infrastructures from the projected increase in climate variability could indirectly contribute to disease transmission. Analysing the role of climate in the emergence of human infectious diseases will require interdisciplinary cooperation among physicians, climatologists, biologists, and social scientists. Increased disease surveillance, integrated modeling, and use of geographically based data systems will afford more anticipatory measures by the medical community (17). There are no more prospective designed study about the climatic parameters and leptospirosis prevalence neither in our country nor in other European countries. İstanbul is a metropolitan city with 13 million population of Turkey and it's located where the continents of Europe and Asia meet. So, our study is important that it's one of the few performed studies in this topic.

Clinicians in developed countries may fail to recognize that leptospirosis transmission occurs in the urban setting because it is incorrectly perceived to be a rural disease. The determination in a short space of time as six months of a total 78 cases of leptospirosis makes one think that, contrary to what was generally believed, leptospirosis may be endemic in İstanbul and probably in other European city centers.

There was no difference between the average temperatures in January and February of 2004-2005 and 2006. In March, however, there was a 2.3 °C increase in temperature compared to January and February. Compared to January and February, the temperature increased by 2.1 °C in March and by 4 °C in April, May and June.

In January and February, rainfall levels were 100% higher compared to March and 400% higher compared to April, May and June in 2004-2005 and 2006. Despite the greater rainfall in January and February no differences were determined in the frequency of leptospirosis cases, which indicates that the increase in environmental temperature is a factor in addition to rainfall.

The numbers of leptospirosis patients in January and February and March 2004-2005 and 2006 were broadly similar, but in April we observed an increase of 50% compared to January, February and March. In terms of total patients in 2004-2005 and 2006, the following increases were observed: January 16.69%, February 19.71%, March 18.98 %, April 44.53%, May 54.23% and June 69.14%. The total number of leptospirosis patients in April, May and June increased considerably ($X^2=3.9, P<0.001$) compared to January, February and March.

Pathogenic leptospires can survive from several days to months in soil, mud and fresh water with a pH in the neutral range, and in the internal organs of animals. In salt water, however, survival time is only a few hours, although this may sometimes be much longer. Leptospira which cannot resist cold and dryness can survive until the following year only by sheltering inside warm blooded animals . The geographical distribution of leptospira varies according to host animal distribution, the local climate and the characteristics of the soil, for which reason leptospirosis cases occur frequently in rainy seasons in which temperatures are over 20 °C (5-7). This indicates that high temperatures and rainfall may have synergistic effects on leptosira transmission.

In terms of rainfall, it is noteworthy that more leptospirosis cases are observed in periods when in addition to high total levels of rainfall there is also a high level of sudden precipitation (April 2006, İstanbul). This may be explained by seemingly unimportant accumulations of water in areas with insufficient infrastructure (such as a sewage system), and the fact that in the event of ideal environmental temperatures these constitute a suitable reservoir for leptospira to survive and reproduce in. It must not be forgotten that since the bacterium is also resistant to environmental temperatures and aridity it can survive for months in water tanks, wells, basements and muddy environments such as damp, alkaline soil, even after the waters have receded. Since there are more than 40 diseases that can be transmitted through water and animal wastes, co-infections (leptospirosis + enteric fever etc) may also emerge. This may pose a danger to health facilities themselves. Patients admitted to hospitals for other reasons may also become infected by leptospiroses as a result of sewage overflows, contaminated water supplies or direct exposure to flooding.

Leptospirosis is a persistent disease and not just a passing epidemic. In many respects, it can in fact be viewed as an emerging infectious disease, notably in underdeveloped and developing countries. We believe that health workers and local administrators should watched out for leptospirosis even in developed regios and countries especially during water associated natural events (tsunami, hurricane-cyclon-typhoons, heavy rains and flooding, mudslides-landslides etc.) when global climate change is on our doorstep.

Conclusion

This pilot study, carried out in a restricted region over a restricted period of time, shows that increases in air temperatures and rainfall are significant factors in the emergence of leptospirosis. Of these two climatic parameters, an increase in air temperatures appears to play a more critical and linear role in the correlation. Together with changes in the ecosystem, global warming poses a serious risk in terms of increasing leptospirosis prevalence. Understanding the linkages between climatological and ecological change as determinants of disease emergence and redistribution will ultimately help optimise preventive strategies. Observation of the correlation between leptospirosis and climatic parameters by means of similar studies over a broader time frame and in different regions will clearly be beneficial.

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CORRELATION BETWEEN TEMPERATURE, RAINFALL AND MALARIA INCIDENCE IN TURKEY

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Marmara University

1. Introduction

This is an interim report on the investigation of the relation between temperature and rainfall changes and malaria incidence in Turkey. Climatic change and its association with the increasing incidence of some infectious diseases has been investigated before [1, 2 and 3]. Malaria is one of the vector borne diseases that is affected by climate change, and the importance of climate as a driving force of malaria transmission has been known since the earliest days of research [4]. Temperature and rainfall may have synergistic effects on malaria transmission and therefore, simultaneous analysis on the long-term series of meteorological and medical data are needed to demonstrate the effects of climate on malaria cases [5].

2. Methodology

In this study, data was collected from two sources:

1. Number of the malaria cases in the last 30 years from the Ministry of Health.

2. Changes in the temperature and rainfall in the last 70 years from The Research Unit of the Turkish State Meteorological Service.

Temperature and rainfall variations and trends for Turkey were analysed using a data set including monthly averages of daily mean, and minimum temperatures. First the non-parametric Kruskal-Wallis (K-W) test is used for a homogeneity analysis. The non-parametric Mann-Kendall (M-K) rank correlation test is then used to detect possible trends in temperature series and to test whether or not such trends are statistically significant, both at the 0.05 level. The M-K test statistic u(t) is a value that indicates direction and statistical magnitude of the trend in a series. When the value of u(t) is significant, it indicates an increasing or a decreasing trend depending on whether it is positive or negative. Cramer test was used to detect the difference in temperature and rainfall between given time periods and the longer period.

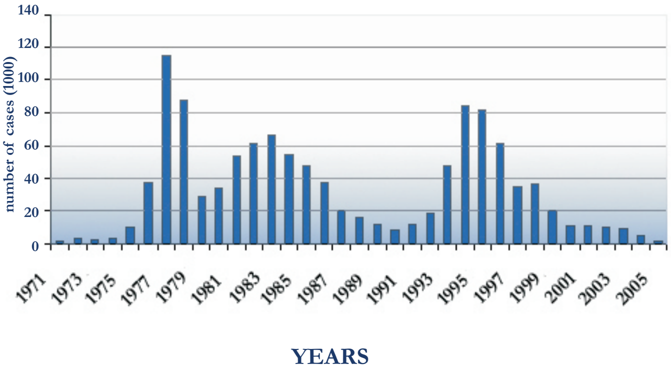

Figure.1 The number of the malaria cases in Turkey since 1971.

In the last 35 years, there have been two important peaks for the number of malaria cases in Turkey, one at the 1977-1984 period, and the other at the 1993-1999 period (Figure 1). However, the distribution of the cases varies in different regions. This finding is interesting and is worth to be explored in more detail. In the 1993-1999 period, there is a significant increase in the number of the malaria cases in southeastern provinces. However the number of the malaria cases did not increase in the same time period in Adana province (Figure 2).

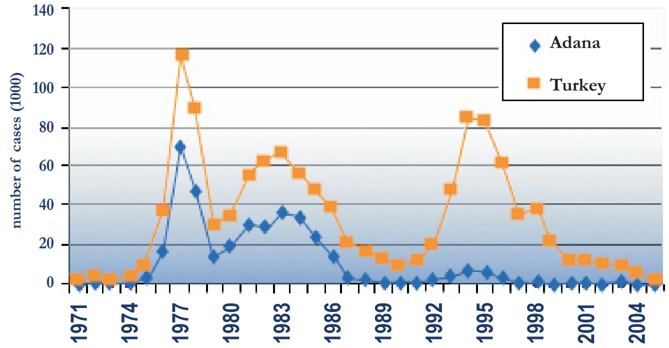

Figure.2 The malaria cases in Turkey and in Adana province since 1971

The number of the malaria cases obtained from the Ministry was verified by data obtained from the clinics, where significant number of malaria cases were admitted. One of these clinics was Ankara Numune Education and Research Hospital and the other was Diyarbakır Military Hospital. Both centers had studies, which show the decline in malaria cases. The researchers from the Numune Hospital indicated that there was a dramatic decline in malaria cases since 1995 (Figure 3) [10]. At the Military Hospital in Diyarbakir, which is in an endemic area for vivax malaria, 609 cases were recorded during the study period (1997-2004) indicating a significant decline in the number of malaria cases in the region [11].

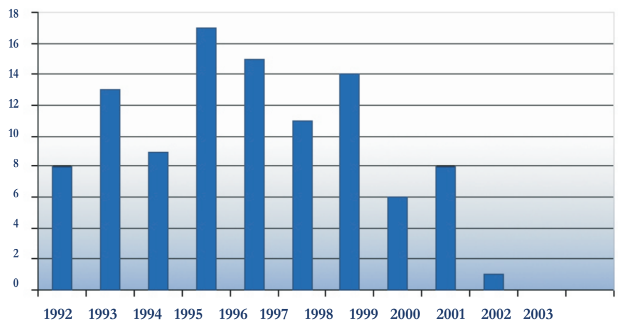

Figure.3 The number of the malaria cases admitted to the Ankara Numune Education and Research Hospital since 1992

3. The Analysis of the Climatic Changes at Sub-periods

The relation between climate change and malaria cases was investigated for two regions separately, the five southeastern and Adana, for two periods characterised by the highest number of malaria cases within the last 30 years.

Within the last 30 years, there are two time intervals characterized by high number of malaria cases. These time intervals were 1977-1987 and 1993-1998 periods. The mean temperature in 1977-1987 period was significantly higher than mean temperature between 1930 and 2004 in Adana. This is a significant result, which shows a parallel between high temperature and the malaria cases within 1977-1987 period. On the other hand, within the same time period, there is no significant increase in temperature in the southeastern provinces, although the number of malaria cases is very high.

In the 1993-1998 period, the mean temperature of Urfa and Mardin were found to be significantly higher than the mean temperatures of the entire period. This can be related to the high number of malaria cases in the region. Alongside this result, within this time period, the number of the malaria cases declined in Adana and there was no significant increase in the mean temperature in Adana.

Table.2 Climatic changes in the southeastern provinces and Adana during two periods.

		Temperature	Rainfall
1977-1987			
Southerneast provinces			
Diyarbakır	(1930-2005)	0.75	0.30
Urfa	(1937-2004)	- 0.82	- 0.73
Siirt	(1993-2003)	0.07	- 0.54
Mardin	(1940-2003)	0.0	1.19
Batman		- 1.70	- 0.23
Adana	(1930-2004)	3.88 (*)	0.41
1993-1998			
Southerneast provinces			
Diyarbakır	(1930-2005)	- 0.42	0.39
Urfa	(1937-2004)	2.18 (*)	0.64
Siirt	(1993-2003)	1.02	0.88
Mardin	(1940-2003)	2.38 (*)	- 0.37
Batman		1.72	1.16
Adana	(1930-2004)	1.58	0.65

(*) shows the significance within this period in comparison with the total duration.
(-) sign shows the decrease, whereas no sign shows positivity, therefore increase.

The number of the malaria cases is related to many other factors. One of these factors is migration, which eventually results in a decline in rural population. Another factor is the coincidental implementation of malaria control programs. The Turkish government and local health authorities have established educational programs to fight malaria. In 1998, as a part of Roll Back Malaria campaign of World Health Organizaton (WHO), an educational project titled "Enhancement of the National Capacity of Malaria Units in Turkey" was launched in cooperation with United Nations Development Programme and WHO. Technical capacity of local malaria units in Southeastern Project Provinces was upgraded and 110 staff members of these units were educated on different aspects of malaria fight including diagnosis, treatment, larvae fight, pesticides etc. [12]. These and similar efforts might have played a great role in malaria control in Turkey.

4. Conclusion

The analyses of temperature changes within certain time intervals seems to reveal a parallel between higher temperature and the number of the malaria cases. It should be emphasised that, although climatic change may play some role on the incidence of malaria, preventive efforts for controlling malaria have a substantial impact. The malaria cases increased in parallel to the increase in mean temperature within certain time intervals. However, the malaria cases declined significantly in Turkey. The primary explanation is the implementation of the control measures.

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Part II:

SECTORAL ANALYSIS AND POTENTIAL MITIGATION MEASURES

GHG Inventory Analysis and Projections

Estimating Carbon Dioxide Emissions in the Turkish Iron and Steel Industry

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1. Introduction

The objective of this study is to determine and estimate CO_2 emissions in the Turkish iron and steel industry for the period 1990-2020. In Spring 2006, a survey was conducted for the industry to determine the total steel production, total CO_2 emissions, specific energy consumption per ton of steel, and specific CO_2 emission per ton of steel from 1990 to 2020.

2. Carbon Dioxide Emissions and Steel Industry

World's primary source of energy are fossil fuels which represent 84% of the total primary energy supply in industrialized countries and 75% in developing countries [1]. Energy production and its use by fuel combustion is largely responsible for the global greenhouse gas emissions. In terms of global warming, the most important greenhouse gas is CO_2. The amount of CO_2 in the atmosphere has increased considerably in the last 150 years reaching 375 parts per million by volume in 2003 [1]. A major aim in this regard is to reduce or control CO_2 emissions.

The iron and steel industry is one of the major energy consuming industries in the world. During iron and steel production, energy is consumed directly using coal, natural gas, electricity and oil. The associated CO_2 emissions resulting from direct use of energy in the industry was estimated to be 7% of the global CO_2 emissions [2,3]. In 1990 and 2004 the total amount of CO_2 emissions in the world was estimated as 20,736 million tons (Mt) and 24,983 Mt respectively [1]. Hence, in 1990 about 1,450 Mt of CO_2 and in 2003 about 1,750 Mt of CO_2 was emitted due to direct use of energy in steel production.

Steel can be produced in integrated steel plants (ISPs) and electric arc furnaces (EAFs). In ISPs the process involves 5 steps: treatment of raw materials, iron making, steel making, casting, rolling and finishing [2]. In ISPs, pig iron is produced by blast furnaces and is then converted to steel in a basic oxygen furnace (BOF) or in an open hearth furnace (OHF). Most of the CO_2 emissions in steel industry occur during iron making in blast furnaces. The coal and coke used in the production of pig iron is responsible for about 75% of CO_2 emissions in the steel industry. Steel making in BOF is more beneficial in terms of energy than steel making in OHF. Hence, currently only a few plants have been left in the world that produce steel by OHF [3].

The amount of CO_2 emissions from iron and steel production is closely related to the type of process (ISP or EAF) and to the specific energy consumed.

In ISPs where steel is produced by BOF the specific CO_2 emission per ton of steel is 2.5 tons whereas in EAF's which use scrap or directly reduced iron, specific CO_2 emissions are reported as 0.6 and 1.2 tons respectively [3]. These values are approximate and may show variation from one country to another.

The difference largely depends on the specific energy consumed in the production of iron and steel. In 1995, one ton of steel production by BOF led to 2.0 tons of CO_2 emission in Europe and in North America, whereas the corresponding figure is nearly 2.5 and 3.9 tons of CO_2 in Japan and China respectively [3]. Similarly, steel produced by EAFs led to emision value of 0.2 ton of CO_2 in Europe, whereas it is 0.4 ton and 0.9 ton in Japan and China respectively [3].

In 1990, about 733.4 Mt of steel was produced in the world and the total has increased to 1035.6 Mt in 2004 [4]. In 2004, 63% of steel was produced by BOF, 34% by EAF and 3% by OHF [5]. In 1990, 9.32 Mt of steel was produced in Turkey (Fig. 1). About 53% of this was produced by EAFs and 47% by ISPs. In the ISPs, 86% of the steel was produced by BOF and 14% by OHF. In 2004, Turkish iron and steel industry produced 20.50 Mt of steel which is about 2% of the world steel production [6]. About 71.5% of this was produced by EAFs and 28.5% of the steel was produced at ISPs by BOF (Fig.1). Since steel production by EAFs leads to lower specific CO_2 emissions, the high EAF steel/BOF steel production ratio of Turkish iron and steel industry in 2004 (0.54 for the world, and 2.5 for Turkey) is beneficial in terms of lower CO_2 emissions.

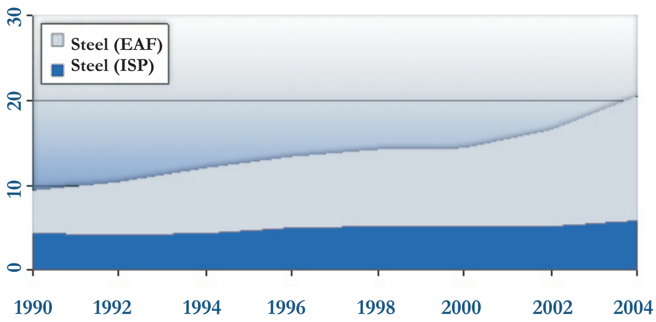

Figure.1 The amount of steel produced by integrated steel plants (ISP) and electric arc furnaces (EAF) in Turkey (6).

3. Turkish Iron and Steel Industry and Carbon Dioxide Emissions

Currently, Turkey produces steel in integrated steel plants (ISPs) using basic oxygen furnaces (BOF) or electric arc furnaces (EAFs). There are 3 ISP and 18 EAF companies in Turkey. These are primarily owned by the private sector, only one EAF company with 60,000 tons of crude steel capacity/year is state owned. In 1990, about 11.28 Mt of CO_2 was emitted from ISPs and 0.743 Mt of CO_2 from EAFs [6]. As shown in Fig. 2, in 2004, total CO_2 emission was about 15.2 Mt, where 87% of this came from ISPs and 13% from EAFs [6]. Expected emissions for 2020 is about 26.54 Mt from ISPs and 2.66 Mt from EAFs [6]. This means that in 2020 more than 90% of CO_2 emissions will be due to emissions from the ISPs.

In the next part of the report, the specific energy consumption and specific CO_2 emission values for the three ISPs of Turkey: Ereğli Iron and Steel Works Co. (Erdemir), İskenderun Iron and Steel Works Co. (İsdemir) and Karabük Iron and Steel Works Co. (Kardemir) will be given with emphasis on energy efficiency studies made between 1990 -2020.

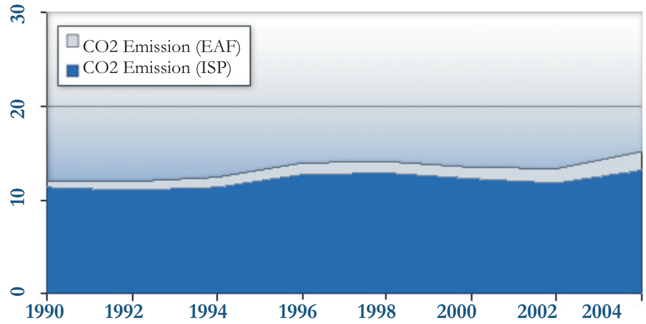

Figure.2 Estimated CO_2 emissions from crude steel production in Turkey, adapted from [6].

3.1 Specific Energy Consumption and Specific Carbon Dioxide Emissions in Integrated Steel Plants of Turkey

In the ISPs, energy consumption is given as 4550-10750 Mcal/ton crude steel(tcs) [2]. This range in specific energy consumption is largely due to the differences in technology, fuel input, operation and maintenance. In the 1990's, steel in ISPs has been produced by BOF process or OHF process. Specific energy consumption for the BOF process is given as 4550 to 9550 Mcal/tcs, whereas specific energy consumption for the OHF process is 7160 to 10750 Mcal/tcs [2]. Hence the BOF process in steel production is more efficient energywise than the OHF process. In 1990, steel in Erdemir and İsdemir was produced by the BOF process, whereas in Karabük it was produced by the OHF process. Specific energy consumption and CO_2 emission values for the ISPs are given in Table 1.

Table.1 Specific energy consumption and specific CO_2 emissions in Erdemir, Isdemir and Kardemir in between 1990 to 2020.

Specific energy consumption (Mcal/tcs)	1990	2004	2010	2015	2020
Erdemir	6665	5125	4977	5614	5683
Isdemir	8340	6420	5300	5000	4800
Kardemir	8950[1]	7347[2]	5750[2]	5250[2]	5000[2]
Specific CO_2 emission (ton CO_2/tcs)	1990	2004	2010	2015	2020
Erdemir	2.16	2.09	2.12	2.07	2.08
Isdemir	2.70	2.51	1.79	1.66	1.65
Kardemir	3.6[3]	1.97[2]	1.97[4]	1.97	1.97

[1] Energy consumption for Karabük in 1990 was not available. This value is between 7150-10750 Mcal/tcs for the steel produced by OHF in integrated steel plants (2). The average of these two figures, 8950 Mcal/tcs, was assumed in this report.

[2] Kardemir, H. Özyiğit, personal communication, 13.07.2006.

[3] Specific CO_2 emission value for Kardemir in 1990 was not available. In 1990, steel at Kardemir was produced by open hearth furnace. Specific CO_2 emission values for this process was assumed to be 3.6 ton CO_2/tcs.

[4] Specific CO_2 emission values for Kardemir in between 2010-2020 were not available. This value is assumed to be 1.97, but reduction is expected when a BOF gas recovery unit becomes operational in 2007.

In the 1990's several estimates have been made of the specific energy consumption for steel produced in ISPs. One estimate was the best value observed which was about 5,250 Mcal/tcs [2]. The second estimate was 6210 Mcal/tcs which is the average specific energy consumption value of major steel producers China, Japan, US and Germany in 1995 [2].

In 1990, the specific energy consumption of Erdemir was reported to be 6665 Mcal/tcs, which is close to the average given above. In the 1990's Erdemir implemented projects and investments to improve specific energy consumption and achieved a value of 5125 Mcal/tcs in 2004, which is better than the best value (5250 Mcal/tcs) reported for 1990's. The major energy efficiency implementations that made this possible included: installing a blast furnace gas holder; BOF gas holder; gas mixing station; modernization of boilers no 3 and 4 for increased use of by product gases; new boiler (no 5) to utilize more by product gases; turbo generator/motor blower (25MW); waste heat utilization and continuous casting instead of ingot casting.

In the 1990's, apart from the energy efficiency applications two major investments were made at Erdemir in order to improve specific energy consumption. One of these allowed the injection of pulverised coal into the blast furnace. The system involves the pulverization of coal and feeding it through under pressure. Injection of pulverised coal replaces a certain amount of expensive coke used in the process with the consequence of energy savings at coke making [7]. The second investment in Erdemir aimed to recover energy in the process gas from BOF. During steel production by BOF, the gas used in the process can be recovered and used as fuel.

These two investments reduced the specific energy consumed as well as specific CO_2 emission in the process. The calculated CO_2 emission savings from these two investments amounts to 200 000 tons of CO2 which constitutes nearly 3.4% of the total CO_2 emissions in 2004. In Table 1, the specific CO_2 emission for Erdemir is given as 2.16 tons CO_2/tcs in 1990, which is slightly higher than the 2.0 tons CO_2/tcs given for Europe and US, but better than the 2.5 tons CO_2/tcs, given for Japan (3). This value was estimated as 2.08 tons CO_2/tcs in 2004.

On the other hand, in 1990, specific energy consumption levels for İsdemir and Kardemir were relatively higher than average levels reported for ISPs (Table 1). Since 1990, like Erdemir, several measures have been taken at İsdemir in order to improve the energy efficiency that included: improvements in coke dry quenching; the use of water vapour from coke dry quenching in turbo blowers; improvements in sintering furnaces; reductions in the use of fuel oil and improvements in the use of product gases. As a result in 2004, a considerable reduction in the specific energy consumption (23%) and in the specific CO_2 emissions (7%) was achieved (Table 1). Investments on increasing the capacity at İsdemir are still continuing. After the completion of these projects by 2010, further reduction in specific energy consumption and specific CO_2 emission will be achieved (Table 1).

In 1990, the high specific energy consumption and the high level of CO_2 emissions at Kardemir was mainly due to the use of OHF process in steel making. In 1999, Kardemir started producing steel by the BOF process with energy efficient continuous casting. These two developments in steel making at Kardemir led to relatively lower specific energy consumption and low specific CO_2 emission values in 2004 (Table 1). BOF gas recovery unit will be active in 2007 and further reductions in CO_2 emissions are expected for the period 2010 to 2020.

3.2 Crude Steel Production and Carbon Dioxide Emissions in Integrated Steel Plants of Turkey

From total crude steel production and the specific CO_2 emission levels given in Table 1, total CO_2 emissions in Erdemir, İsdemir and Kardemir, for the years 1990 to 2020 are computed; as indicated in Table 2.

Table.2 Crude steel production; related total and specific CO_2 emissions for integrated steel plants in Turkey.

Crude steel production (Mtcs)	1990	2004	2010	2015	2020
Erdemir	1.94	3.03	3.15	5.91	5.91
İsdemir	1.82	2.09	6.25	6.25	6.25
Kardemir	0.605	0.828	1.22[1]	1.25[1]	2.00[1]
Total crude steel production	4.36	5.95	10.62	13.41	14.16
CO_2 emission (Mt/year)	1990	2004	2010	2015	2020
Erdemir	4.19	6.33	6.68	12.23	12.29
İsdemir	4.91	5.25	11.19	10.37	10.31
Kardemir	2.18[2]	1.63	2.40[3]	2.46	3.94
Total CO_2 emission (Mt/year)	11.28	13.21	20.27	25.06	26.54
Specific CO_2 emission (ton CO_2/tcs)	2.59	2.22	1.91	1.87	1.87

[1] Estimates for crude steel production for the years 2010-2020 were not available; only those for pig iron were provided in the survey. For the years 2010 -2020 these values were taken into consideration.

[2] Specific CO_2 emission for Kardemir was not available. In 1990 steel at Kardemir was produced by open hearth furnace and the specific emission for this process is assumed to be 3.6. CO_2 emission for 1990 is calculated from this value.

[3] Specific CO_2 emissions for Kardemir in between 2010-2020 were not available. This value is assumed to be 1.97 ton CO_2/tcs. However, further reduction in this value is expected because of the BOF gas recycling unit which will be operative in 2007.

In 1990, 4.36 Mt of crude steel was produced in the three ISPs of Turkey. The estimated CO_2 emission from this was about 11.28 Mt; with corresponding specific CO_2 emission level of 2.59 ton CO_2/tcs (Table 2). In 2004, total steel production by ISPs was 5.95 Mt which corresponds to an increase of 36.5% relative to 1990. Within the same period CO_2 emission from the ISPs increased by 17% and reached 13.21 Mt in 2004. The corresponding specific emision level however, dropped to 2.22 ton CO_2/tcs in 2004 despite the increase in production. As stated above, within the period 1990-2004, ISPs made investments in order to reduce the specific energy consumption and hence specific CO_2 emissions. Due to these developments in the sector a considerable amount of reduction in the CO_2 emission was achieved. In 2004, the amount of CO_2 saved, due to the energy efficiency studies and improvement in technology, was calculated to be 2.2 Mt of CO_2 .

According to projections, crude steel production in integrated steel plants will reach 10.62 Mt in 2010; 13.41 Mt in 2015; and 14.16 Mt in 2020 (Table 2). This implies an increase in total CO_2 emissions from ISP's for 2010, 2015 and 2020, totaling 20.27 Mt, 25.06 Mt, and 26.54 Mt respectively (Table 2). However, as stated in the previous section, Erdemir, İsdemir and Kardemir are all making investments in order to increase capacity and to reduce specific energy consumption. Due to these developments in the sector, as shown in Table 2, further reduction in the specific CO_2 emission values can be expected.

4. Conclusions

This study reported CO_2 emissions related to direct use of energy in the Turkish iron and steel industry. A survey was conducted in the sector and specific energy consumption as well as specific CO_2 emission levels were determined for the years 1990, 2004, 2010, 2015 and 2020. Total CO_2 emissions related to steel production were estimated from total production and specific CO_2 emissionlevels. A summary of the results is given in Table 3. A part of the data given in Table 3 was obtained from Turkish Iron and Steel Producers' Association [6].

Table.3 Total crude steel production, CO2 emissions, and specific CO2 emission levels from ISPs and EAFs in Turkey for 1990 - 2020.

Crude Steel Production (Mtcs)	1990	2004	2010	2015	2020
Integrated Steel Plants	4.36	5.95	10.62[1]	13.41[1]	14.16[1]
Electric Arc Furnaces	4.95	14.65	17.75[2]	18.95[2]	19.70[2]
Total	9.31	20.5	28.37	32.36	33.86
CO_2 Emission (Mt CO_2)	1990	2004	2010	2015	2020
Integrated Steel Plants	11.29	13.22	20.25	25.06	26.54
Electric Arc Furnaces	0.74	1.98	2.4	2.56	2.66
Total	11.96	15.2	22.65	27.62	29.2
Specific CO_2 Emission (ton CO_2/tcs)	1990	2004	2010	2015	2020
Integrated Steel Plants	2.59	2.22	1.91	1.87	1.87
Electric Arc Furnaces[3]	0.150	0.135	0.135	0.135	0.135

* Mtcs - million ton crude steel

[1] These figures are obtained from Erdemir, Kardemir and İsdemir. For Kardemir, projections from pig iron output were used since steel production data was not available.

[2] Estimated from the data obtained from [6].

[3] Specific CO_2 emission levels given for electric arc furnaces was obtained from the "Inventory Study of CO_2 Gas Emissions for Iron and Steel Industry" compiled by the Turkish Iron and Steel Producers' Association [6].

Analysis of Table 3 yields three main conclusions with regard to the CO_2 emissions from steel production in Turkey.

1. For the period 1990-2004, the amount of crude steel produced has increased from 9.31 Mt to 20.5 Mt. In 1990, 53% of the crude steel was produced by EAFs and 47% by ISPs; whereas in 2004, 71.5% was produced by EAFs and 21.5% by ISPs. As explained in Section 2, in terms of CO_2 emissions, steel production with EAFs is better than production by ISPs. In the Turkish iron and steel industry, in 1990, specific CO_2 emission values for EAFs was estimated as 0.150 ton CO_2/tcs (6). This specific emission is lower than the 0.2 ton CO_2/tcs level given for EAF production in Western Europe in 1995 (3). It is of course much lower than specific CO_2 emission given for ISPs which has been estimated to be 2.22 tons in 2004 (Table 3). In 2004, about 1035.6 Mt of steel were produced in the world and 34% of this amount was produced by EAFs. It seems that, the high proportion of steel produced by EAFs in Turkey is a significant advantage in terms of lower CO_2 emissions and meeting the Kyoto targets.

2. Comparison of estimated specific CO_2 emissions from ISPs in 1990 and 2004, show a decrease from 2.59 ton CO_2/tcs to 2.22 ton CO_2/tcs. This is about 14% reduction in specific CO_2 emission. As explained in Section 3.1 and Section 3.2, this reduction is due to investments made to reduce energy consumption in crude steel production and investments made to replace OHF technology with BOF technology. In 2004, the amount of CO_2 saved due to these investments was estimated as 2.2 Mt.

3. Comparison of estimated specific CO_2 emissions of ISPs in 2004 with those in 2010, 2015 and 2020 also show a decrease from 2.22 ton CO_2/tcs to 1.87 ton CO_2/tcs. This implies that within the next 15 years steel will be produced with less specific energy consumption and hence with lower CO_2 emissions. In the three ISPs in Turkey, capacity and efficiency investments are still going on. Hence, it is fair to say that ISPs are in the process of restructuring in order to meet the global challenge of reducing the energy costs, CO_2 emissions, and producing low cost high quality steels.

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GREENHOUSE GAS EMISSIONS IN THE TRANSPORTATION SECTOR IN TURKEY; INVENTORY ANALYSIS AND PROJECTIONS

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1. Introduction

The aim of this study is to compile and present data for greenhouse gas (GHG) emissions resulting from the Transport Sector in Turkey for 1990 - 2004, and analyse the methods and possibilities of future improvements for the reduction of GHG emissions.

National inventory of transport based GHGs in compliance with the revised IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997) and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000), are compiled to ensure that emission estimates are accurate, transparent and comparable with those of other countries. Consistency through time is also aimed for maintaining accuracy. Uncertainty range for the inventory data is also estimated.

According to the IPCC Tier 1 approach, transport based GHGs such as carbon CO_2, methane (CH_4) and nitrous oxide (N_2O) are compiled on an energy comsumption basis. Indirect GHG emissions such as carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOC) are also estimated. Since vehicle technologies and operating conditions have a considerable effect on emissions, the IPCC Tier 2/3 approach is adopted for the refinement of estimations for road vehicles, aviation and railways.

The report also includes a comparison of Turkey's present and past situation with UNFCCC (United Nations Framework Convention on Climate Change) Annex I and Kyoto Protocol Annex B countries in terms of production and CO_2/capita, CO_2/GDP consumption with regards to the transport sector.

2. Methodology for Estimating Emissions

Emissions of the three direct greenhouse gases (CO_2, CH_4 and N_2O) resulting from energy consumption in the transport sector and also indirect GHG emissions such as CO, NO_x, NMVOC and SO_2 are covered in the inventory.

Transportation consists of road transportation, domestic civil aviation, railways and national navigation. Emissions from international aviation that cannot be allocated to the national inventory are usually reported seperately as unallocated emissions. In this study fuel consumption data related to aviation was provided only for domestic consumption. Therefore no results are provided in this report for unallocated emissions resulting from international aviation.

The following sections of the report provide information on data sources of the inventory and methodology for energy based computation of GHG emissions for road transportation, domestic aviation and rail transportation using both Tier 1 and Tier 2/3 approaches. Data limitation does not allow any estimations for the navigation sector using methodology other than Tier 1. Methods of calculation are based on the IPCC recommendations. Some modifications are made for road transportation according to country specific conditions as explained in detail in the following sections (Section 2.2). The relevant data is requested from the authorities for all activities. The data received is verified and examined for consistency and anomalies and cross checked with equivalent data received from other sources.

The data is processed for GHG emission estimations and outcomes are checked for time series consistency, together with trends in fuel consumption affected by national economical conditions through the time interval.

The data processed in this work has not been subjected to statistical analysis; therefore uncertainties are checked for consistencies and time series trends. Diesel fuel consumption is also analyzed and remarks are presented in a seperate section on uncertainties.

2.1 The Data Sources

The fuel based approach is used to estimate GHG emissions. Emission factors used in IPCC Tier 1 approach are based on the heat content of the fuel used, the fraction of carbon in the fuel that is oxidised during combustion and the carbon content coefficient. Combustion efficiency is assumed to be 99% in most cases, depending on the fuel used.

Emission factors for different fuel types are used according to default values indicated in the IPCC approach. For carbon emissions, carbon mass emitted is proportional to the mass of fuel consumed. Therefore fuel based CO_2 emissions are directly obtained by the application of emission factors to the fuel consumed. For other GHGs, appropriate emission factors are used according to IPCC default values.

The GHG inventory was initially compiled according to IPCC Tier 1 approach using fuel consumption data provided by the Ministry of Energy [3].

In the road transport sector, which is the key source for GHG emissions, there is certain inconsistency in the data obtained from different sources. Hence fuel consumption values from different sources are analysed for verification purposes. Fuel consumption data obtained from the Ministry of Energy [3] is considered as the most accurate data and used for the computations to estimate GHG emissions. Other information received from Turkish Automotive Manifacturers Association (OSD) and data obtained from Petroleum Manufacturers Association of Turkey (PETDER) [4] are compared with these values.

In the available data diesel fuel consumption was not specified for each type of consumer such as road vehicles, agricultural machinery, construction and utility vehicles/machinery and power generators. Data is unavailable for the number of generator units and registered utility vehicles. This issue is discussed in the analysis of accuracy, but as the contribution on total emissions of those sources, other than diesel engined road vehicles, is very limited, only registered road vehicles have been taken into consideration. The total diesel fuel consumed by road vehicles in Turkey also involves some unregistered fuel entering the country over the border mainly from the south-eastern part of the country. This low quality unregistered fuel is reported by PETDER after an analysis of the changes in total number of vehicles, the total fuel requirement and total fuel sales over the years [5]. This analysis is discussed in Section 3.

The fleet population for various categories of road vehicles is provided by the Turkish Statistical Institute (TURKSTAT, TUİK) [6]. For technological classification of the vehicle fleet in each calendar year, data from the Turkish Automotive Manufacturers Association (OSD) on exhaust emission legislations is used [7]. Vehicle-km values for diesel powered vehicles are obtained according to estimates from available statistical results with reasonable assumptions.

For railways additional fuel consumption data obtained from the TCDD (Turkish State Railways) Research, Planning and Coordination Department [8] for time series 2000 – 2004 has been used. Although this data is inconsistent with the data provided from the Ministry of Energy [1], the trends are in agreement and for the period from 2000 to 2004, this data is used.

The fuel consumption data provided by the Ministry of Energy for aviation does not differentiate between domestic and international flights. Initially, GHG emissions were estimated using total fuel consumption data according to the IPCC Tier 1 approach. These calculations were then refined to estimate GHG emissions seperately and to include only the domestic emissions in the national inventory according to IPCC Tier 2 approach (not including international aviation). Landing and take off (LTO) values for each airport in Turkey for time series 1990 – 2004 have been used. The percentage of domestic and international flights in all airports are also considered in calculating the amount of fuel consumed for LTO and cruise consumption for domestic purposes only [9]. Although emission factors for all the airplane types on the list were not available, the magnitude of fuel consumption values indicated that the data provided by the Ministry of Energy was only for domestic aviation. The results of this analysis lead to GHG emissions estimate of domestic aviation in both Tier 1 and Tier 2 approaches.

2.2 Road Transport

Road vehicles powered by internal combustion engines are one of the major sources of pollutant emissions such as CO, unburned HC's, NO_x and particulate matter (PM) that are controlled with emission legislations in force. CO_2 is also a principal product of combustion and its production is directly related to the amount of fuel consumed by the vehicle. Other GHG gasses reported in this inventory such as CH_4 and N_2O are also emitted through the combustion process. CH_4 is a hydrocarbon resulting from the incomplete combustion of fuel that is induced into the combustion chamber. N_2O is a product resulting from the partial oxidation of nitrogen which is present in the air, during the combustion process in the engine. N_2O is also produced in the exhaust system of passenger cars with catalytic converters.

In the present inventory study, GHG emissions from road transport are calculated from fuel consumption data according to the specifications and the amount of various fuels used in this sub-sector. Refinements on IPCC Tier 1 approach have been carried out applying modifications considering road traffic data and emission factors for a variety of vehicle technology groups for emissions other than CO_2 and SO_2 which are obtained directly from fuel consumption. CO_2 emissions are estimated using the yearly consumption of gasoline, diesel and LPG fuels and the calculations are based on the carbon content of each fuel.

Emissions from vehicles running on natural gas are not included in the present inventory, as the number of these vehicles is very low and their contribution is negligible.

SO_2 emissions are also calculated from the fuel consumption data and the estimated sulphur content of the fuels in Turkey, according to the IPCC Tier 1 fuel-based emissions approach.

The emissions of pollutants such as NO_x, NMVOCs, CO, CH_4 and N_2O depend on,

(i) Vehicle specifications such as engine type, size, applied emission control technology,

(ii) Fuel type and specifications (gasoline, diesel fuel, LPG, natural gas),

(iii) Traffic related driving conditions and patterns.

The IPCC Tier 2/3 methodology has been used in this project to refine emissions resulting from road transport in addition to the Tier 1 approach described previously.

For the estimation of traffic-based emissions, vehicle data in terms of fleet size in each category, emission factors according to fuel types and vehicle specifications, distance covered per vehicle in each category has been used (see Table.1 to Table.8).

This method is verified by recalculating the CO_2 emissions and comparing them with the results of the Tier 1 approach.

Vehicle fleet composition by size and fuel type is given in categories as,

(I) Passenger cars - gasoline

(ii) Passenger cars - LPG

(iii) Passenger cars - diesel

(iv) Buses and minibuses (diesel)

(v) Light-duty and heavy-duty trucks (diesel)

(vi) Motorcycles (two-stroke engines, gasoline)

Data related to the number and distribution of road vehicles has been provided by the TURKSTAT. Fuel consumption data for the road transport sector has been obtained from the Ministry of Energy. Additionally, OSD provided yearly data for new vehicle registrations resulting from domestic manufacturing. The vehicle distribution according to technology utilised (the pollutant emission regulations) has been calculated for each year through the information provided by OSD (Table.1).

The passenger car fleet composition is divided into vehicles gasoline and diesel engines using the diesel engine percentage for 2004. Diesel percentage for previous years is estimated to be at much lower values due to the fact that dieselisation trend has been growing only very recently.

Accurate data for the passenger car fleet, including new registrations and deletions from the registers, is only available after 1995. So 1995 is considered as the base year and passenger cars entered in and deleted from registers at the Trafic Registration and Control Division is used to obtain the sub-divisions of passenger car fleet according to vehicle age, technology and fuel type.

Milage for vehicles is obtained from the known data of total yearly fuel consumption and default unit fuel consumption data (liters/100 km) for each technology group according to IPCC Tier 2/3.

Emissions resulting from vehicles running on LPG are estimated using the number of passenger cars that are registered as running on LPG, and the fuel consumption values provided by the Ministry of Energy. It is believed that the actual number of cars fueled with LPG exceeds this official value as all the conversion is not registered and also some non-transport fuel other than auto-gas is consumed in those vehicles.

Actual diesel fuel consumption is also higher than the official values provided by the Ministry of Energy. Unregistered fuel entering the country over the border is believed to be the source for the differences observed.

Calculations are carried out using the default emission factors given in IPCC; country specific emission factors are not used as no drive cycle is available at the present for the characterisation of local conditions.

Table.1 Changing of the vehicle park in Turkey through 1990-2004

Years	Passenger Car	Truck	Pick-Up	Minibus	Bus	Farm Tractor	Total
1990	1.649.879	257.353	263.407	125.399	63.700	692.454	3.052.192
1991	1.864.344	273.409	280.891	133.632	68.973	704.373	3.325.622
1992	2.181.388	379.410	308.180	145.312	75.592	828.580	3.918.462
1993	2.619.852	406.398	354.290	159.900	84.254	870.559	4.495.253
1994	2.861.640	419.374	374.473	166.424	87.545	895.506	4.804.962
1995	3.058.511	432.216	397.743	173.051	90.197	937.528	5.089.246
1996	3.274.156	453.796	442.788	182.694	94.978	988.142	5.436.554
1997	3.570.105	489.071	529.838	197.057	101.896	1.053.381	5.941.348
1998	3.838.631	519.749	626.004	211.495	108.361	1.107.157	6.411.397
1999	4.072.326	531.690	692.935	221.683	112.186	1.131.626	6.762.446
2000	4.422.180	557.295	794.459	235.885	118.454	1.159.070	7.287.343
2001	4.534.803	562.063	833.175	239.381	119.306	1.179.068	7.467.796
2002	4.600.140	567.152	875.381	241.700	120.097	1.180.127	7.584.597
2003	4.700.343	579.010	973.457	245.394	123.500	1.184.256	7.805.960
2004	5.400.440	647.420	1.259.867	318.954	152.712	1.210.283	8.989.676

2.3 Domestic Aviation

Domestic aviation emissions resulting from gasoline and jet kerosene are estimated in the inventory according to fuel consumption data obtained from the Ministry of Energy.

Number of landing-and-take off (LTO) for each airport in Turkey, for all airplane types is provided by the Ministry of Transport, DLH Department [9]. Ratio of domestic to international flights in global terms is also provided. This ratio is used to estimate domestic LTO numbers assuming that this global value is applicable for all circumstances. Using IPCC default values and engine specific emission factors, GHG emissions are obtained by the Tier 2 approach. For those airplane types that the specifications were not available, IPCC defaults were utilised.

According to the Tier 2 method, number of LTO values for each aeroport and default fuel consumptions are used to calculate fuel consumed during the LTO phase. This is then substracted from the total fuel consumption to obtain fuel consumed through the cruise phase. These are then used to estimate emissions.

2.4 Rail Transport

In Turkey locomotives are primarily powered by diesel engines. Rail transport emissions resulting from diesel fuel are reported in the inventory according to the fuel consumption data obtained from the Ministry of Energy, using the IPCC Tier 2 approach for GHG emissions other than SO_2.

Refined data obtained from TCDD (Turkish Republic State Railroad Administration) for the period from 2000 to 2004 is used for those years replacing Ministry of Energy data [8].

2.5 National Navigation

National navigation emissions resulting from diesel fuel and fuel oil are reported in the inventory according to the fuel consumption data obtained from the Ministry of Energy, using the IPCC Tier 1 approach according to fuel based calculations. Default emission factors are used in the calculations.

3. Uncertainties

Uncertainties are inevitable in any estimate of sectoral GHG emissions due to implementation of average emission factor in the computations, uncertainties in the basic activities considered and inherent uncertainties in the scientific understanding of the basic activities. IPCC methodology used in this work aims to minimise the level of uncertainties in estimations.

The calculations involve IPCC Tier 1 and Tier 2/3 approaches implementing IPCC default emission factors most of the time rather than country specific values. Therefore no statistical data is used.
For the aviation sector, default IPCC uncertainties are used both for emission factors and activity data. Total uncertainty of 10% is obtained for aviation, with default 7% uncertainties for emission factors and activity data.

For other sub-sectors of transportation, generally higher uncertainties apply than IPCC default values.

In railways and navigation sub-sectors, IPCC default values of 7% uncertainties for emission factors and activity data (mainly fuel consumption) are increased by 50% reaching 10.5%. In this case uncertainties reach a value of 15 % in total.

For road transportation higher total uncertainties are estimated reaching 20% especially for the years 2003 and 2004. This results from uncertainties in the consumption of diesel fuel for transportation. Fuel consumption data provided by the Ministry of Energy is used in the calculations.[3] Comparing this data with that of PETDER, indicates a variation of almost 50% in diesel fuel and LPG consumptions both for national totals and regional consumption figures.[4] This is partly due to the fact that diesel is consumed for purposes other than transportation, such as electricity generation, heating and household needs. This could add up to 25% of the total consumption.

Another source of uncertainty in diesel consumption arises from the fact that considerable amount of diesel fuel is brought into the country over the border. This amounts to 1,5 Mton in 2003 and 0,9 Mton in 2004 as indicated in the PETDER (Petroleum Producers Association) report[5]. Likewise the amount of gasoline brought into the country by the same means is in the range of 1 Mton per year in 2003 and 2004 according to the same report. This can also be observed from the differences arising in CO_2 estimations according to the Tier 1 approach based on fuel consumption only and Tier 2/3 approach which consider number of vehicles in the fleet, milage covered yearly and emission factors according to technology level of the vehicle.

4. Results

This inventory study was performed in two consecutive stages. Initially for all sub-sectors, energy based IPCC Tier 1 methodology has been used. The second stage involves the refinement of Tier 1 results, by applying IPCC Tier2/3 methodology for road transport, aviation and railways.

Trends in mainly CO_2 and all other GHG emissions resulting from combustion of fossil fuels used in the transportation sector are influenced by economic conditions and fuel prices on a yearly basis. The influence of economic crises is clearly observed and in these periods, total fuel consumption is considerably reduced. Economic crisis also affects the number of newly registered vehicles in those years. However in general the total number of vehicles, especially passenger cars are increasing. Increase in population and GDP are major factors that influence this trend, along with other social and economical conditions.

Long term GHG emission trends are influenced by,

(i) The increase in the number of vehicles over the years,

(ii) Improvements in vehicle efficiency according to technological developments that reduce fuel consumption per unit distance travelled,

(iii) Developments in consumer behaviour resulting in changes of transportation mode such as public transportation, walking for short distances or cycling etc.

(iv) Changes in traffic flow patterns and conditions.

Turkey's present position in terms of vehicle ownership, compared to European countries and the industrialised world indicates the clear potential for increase in the number of vehicles. The expected trend is continued increase in the number of passenger cars until saturation is reached. This implies a potential for increase in transport related fuel consumption and GHG emissions if not managed correctly.

The population of Turkey is increasing at an average rate of 1.8% through the years 1990 to 2003. The population would rise to approximately 80 000 000 in 2010, keeping the same growth rate.

Table.2 Change of population in recent years

Census Year	Population
1975	40 347719
1980	44 736 957
1985	50 664 458
1990	56 473 035
2000	67 803 927
2003	70 700 000

Alternative fuel use with low carbon content also reduces the emission of CO_2. Diesel fueled and LPG fueled passenger cars show a reduction in GHG emissions due to higher efficiency obtained and favourable fuel specifications. Natural gas use in road vehicles is very limited in Turkey, the only application being a fleet of city buses in certain districts of İstanbul and Ankara; hence the contribution in terms of pollutant emissions is negligible. Short term reduction of GHG emissions would benefit from the increase of natural gas fuelled vehicles in case of legislative action such as tax advantages.

Dieselisation is a rising trend in Turkey. Diesel powered vehicles are more efficient than equivalent gasoline powered vehicles and CO_2 emissions are lower per unit distance travelled. Therefore increase in diesel percentage over the whole passenger car fleet would benefit from emission reductions.

In Figure.1 the contribution of vehicle categories to CO_2 emission is given. Almost 75% of CO_2 emissions is from passenger cars, trucks and buses. The clear increase in contribution of light-duty vehicles (LDV) and trucks can be seen from the figure. Same trend can be observed for other emissions such as NO_x, as indicated in Figure.2.

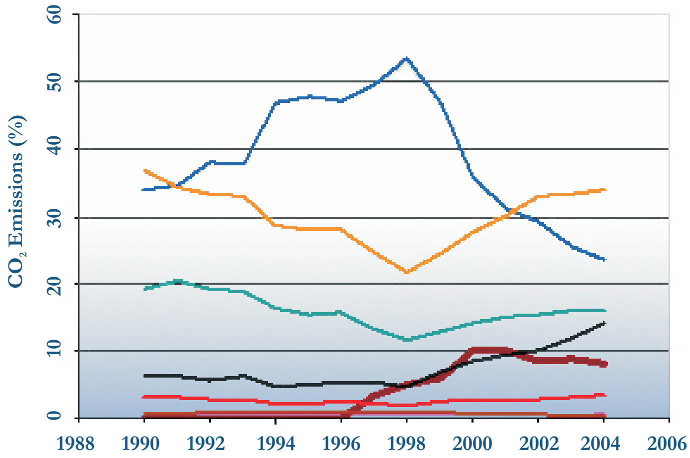

Figure.1 Contribution of vehicle classes to CO_2 emission

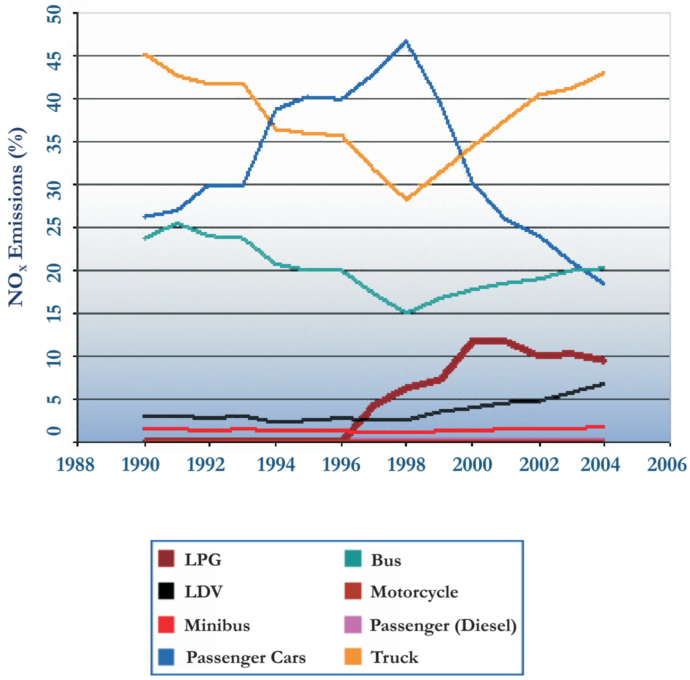

Figure.2 Contribution of vehicle classes to NO_x emission

Technological developments in engines and vehicles is one of the major factors that influence GHG emissions resulting from transportation. In recent years, starting from 1994, EURO I emission regulations are put into action in Turkey in order to reduce CO, unburned HC and NO_x emissions. Advanced technologies used in those vehicles also reduced fuel consumption and therefore CO_2 emissions.

Table.3 indicates the number of gasoline engined passenger cars in different emission categories. At present, cars without emission control and of the class 15.04 still consist of 60% of the total number. IPCC default emission factors for NO_x emission for these classes are almost 4.5 times more than Euro III stage. So it is expected that nearly 87% of NO_x emission of gasoline vehicles is from this category. Similarly, nearly 75% of CO_2, 80% of CH_4, 95% of NMVOC and 95% of CO are emitted from these cars.

Table.3 Number of gasoline vehicles in each technology category

Years	Number of passenger cars (Gasoline + LPG)	Number of vehicles (Euro III)	Number of vehicles (Euro I)	Number of vehicles (Uncontrolled +15.04)
2004	4761312	707816	1198204	2855293
2003	4615474	275903	1198204	3141367
2002	4516428	181759	1198204	3136465
2001	4454285	114822	1198204	3141259
2000	4347429	0	1091460	3255970
1999	4007411	0	742846	3264565
1998	3777970	0	511547	3266423
1997	3514574	0	304979	3209595
1996	3219035	0	128761	3090274
1995	3009453	0	54170	2955283
1994	2818488	0	28185	2790303
1993	2583954	0	0	2583954
1992	2154259	0	0	2154259
1991	1843556	0	0	1843556
1990	1633380	0	0	1633380

Removing old cars from the registers would bring significant improvement in both CO_2 and other emissions. Indeed, the reduction of CO_2 emissions is calculated to be in the range of 4.87% due to retiring these vehicles by providing tax incentives to consumers. In 2003 and 2004, tax incentive provided for retired passanger cars added up to 325,481 vehicles. When compared with the number of retired vehicles in regular years, there is an indication that almost 320,000 vehicles were retired due to the tax incentive provided, which adds up to 4.87% reduction in the CO_2 emissions of passenger cars in those two years. The number of passenger cars with uncontrolled emission technology provides a potential of further gain by the use of a similar application until some 2,500,000 cars are deleted through this method.

Considering only the vehicles that are older than 15 years, this number adds up to 1,500,000. It is therefore possible to decrease the emissions further by 20 - 25% by deleting these vehicles from the registers in short term.

Introduction of advanced technology vehicles reduce GHG emissions, except CO_2. Although advanced emission control systems were partly mandatory during the years 1994 to 2000, a noticeable effect can be seen starting from year 2001, where all new gasoline engined passenger cars meet EURO III limits. CO_2 emissions in this case slightly increase due to higher fuel consumptions to meet the lower emission limits.

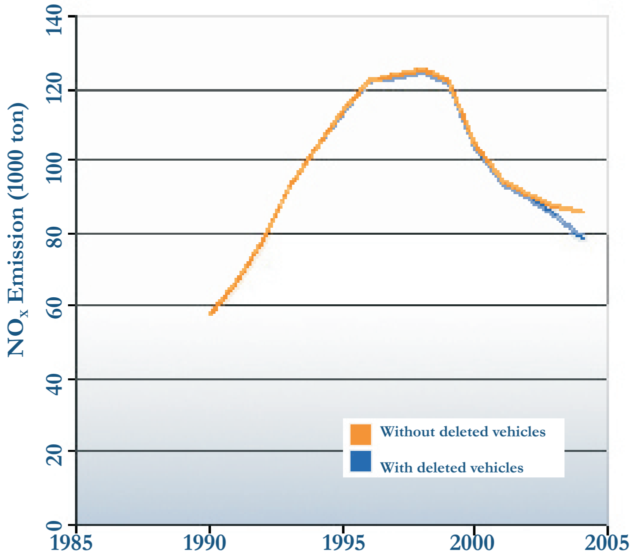

Figure.3 Effect of new technology on NO_x emission

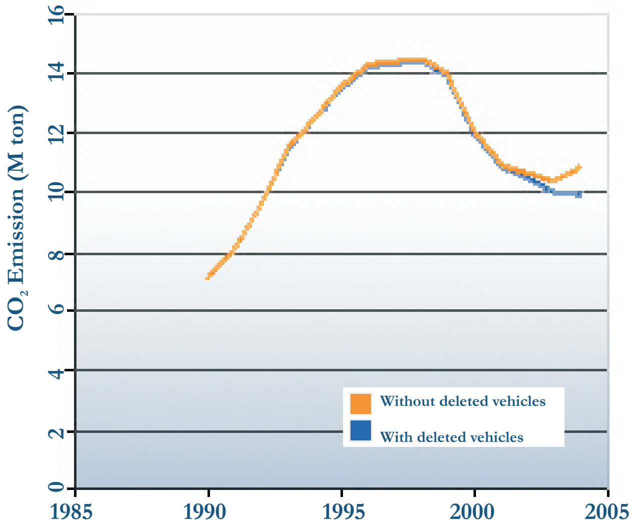

Figure.4 Effect of new technology on CO_2 emission

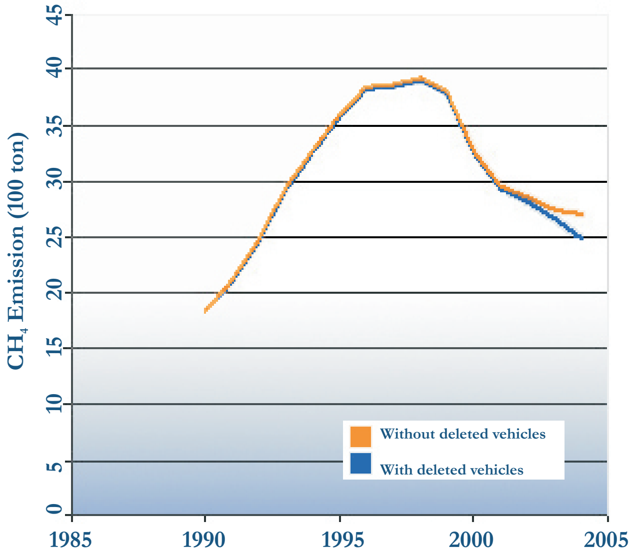

Figure.5 Effect of new technology on NMVOC emission

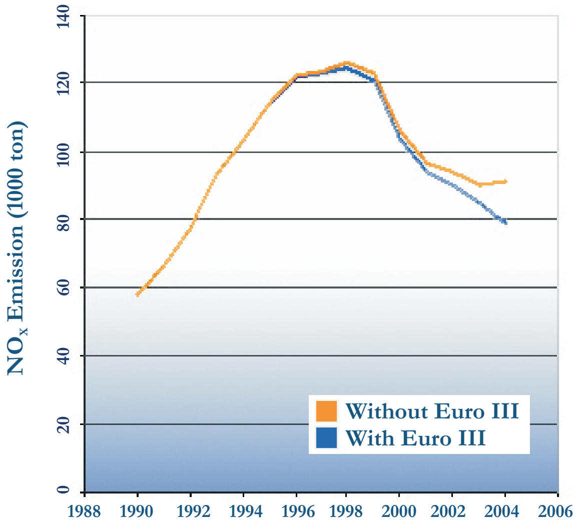

Figure.6 Effect of new technology on NO_x emission

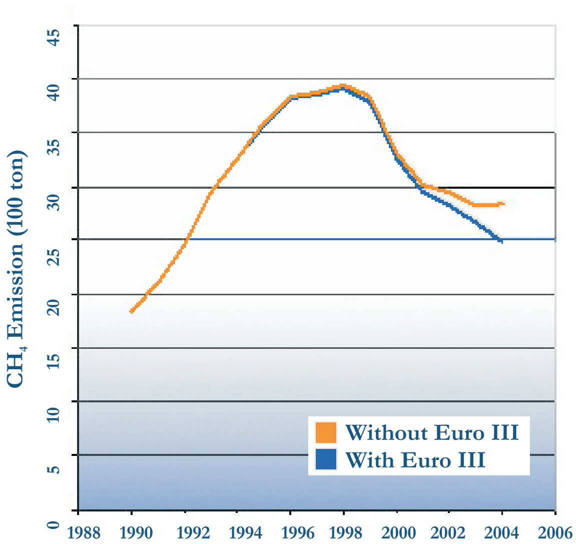

Figure.7 Effect of new technology on CH_4 emission

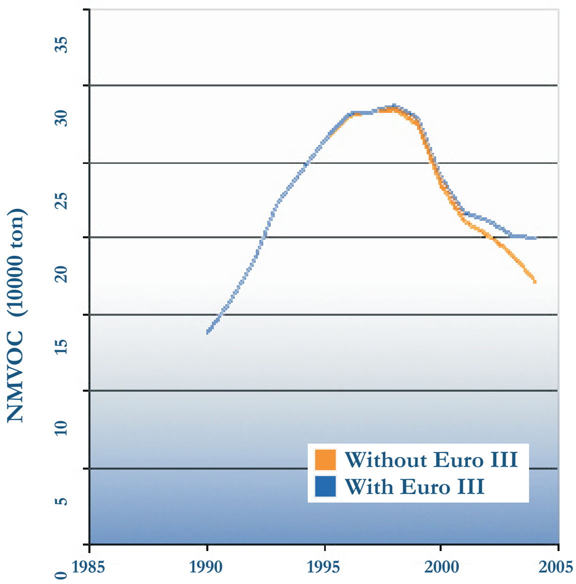

Figure.8 Effect of new technology on NMVOC emission

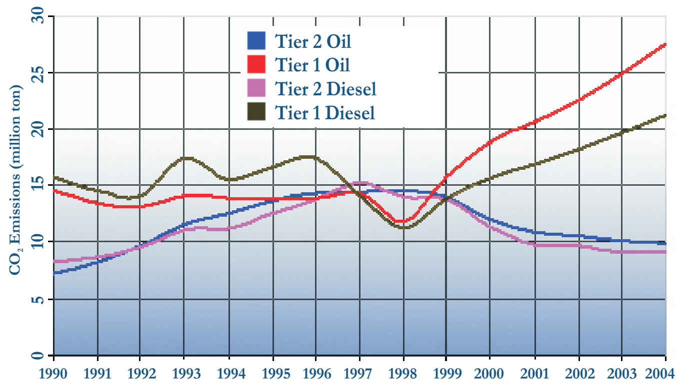

Figure.9 CO_2 Emissions from road transport obtained by Tier1 and Tier 2/3 approaches

Figure.9 illustrates CO_2 emissions from road transport, estimated by Tier 1 and Tier 2/3 approaches. In the Tier 2/3 approach, IPCC default fuel consumption values and estimated yearly travel distances of the vehicle classes are used. Agreement between the two approaches indicates that assumptions made for obtaining yearly travel distance estimations are realistic. The difference between the default emission factors and national specific emission factors is one factor that causes the observed deviations especially in recent years.

The deviations in CO_2 emissions resulting from diesel fueled vehicles, between Tier 1 and Tier 2/3approaches is also the result of extra fuel supplied into the market over the border and it is not included in the official figures. That trend is clearly observed after 1999. From figures it is seen that there is a tendency to keep the levels in emissions after 2003 in case of vehicles without EURO III emission control systems. This is due to the increasing number of diesel vehicles which do not meet the new emission limits due to the unavailability of proper quality diesel fuel. It must be pointed out that after 2007 it will be possible to find low sulfur diesel fuel and this picture will change. Besides, the relative increase in emissions after 2003 could be compensated by introduction of gasoline vehicles of Euro III and Euro IV levels.

A projection indicates that the number of total light and heavy duty commercial vehicles will reach to 2 550 000 units in the year 2010. This corresponds to a 21.5% increase relative to 2004 values, meaning that to maintain the present CO_2 emission levels, these vehicles must consume 21.5% less fuel on average. But improvement in fuel consumption to that level is not expected.

Number of passenger cars, including diesel vehicles will also reach 5,700,000 in 2010 according to the projection indicated with an increase of 17% compared to 2004 figures. It seems possible to compansate for this increase in vehicle fleet size by improvement in fuel consumption technology.

5. Conclusions

The GHG emissions resulting from the transport sector in Turkey show a rising trend, compared to the reference year of 1990. The rise in population and improvements in economical circumstances are major factors that result in an increase in energy consumption which in turn leads to increasing GHG emissions.

The total transport based CO_2 emissions compared to year 1990 has changed from 25.954,63 Gg to 40457.82 Gg in the year 2004, with an increase of 55.8%. This corresponds to a change from 0.46 ton CO_2/capita in 1990 to 0.57 ton CO_2/capita in 2004.

The CO_2 emissions from transport sector has changed from 0.17 kg CO_2/$ in 1990 to 0.14 kg CO_2/$ in 2004. This improvement shows efficient energy consumption tendency in the sector.

Sustainable transportation in Turkey, as in the rest of Europe can be achieved through technological changes that result in improvements of existing vehicle and engine technologies and development of new, low pollutant emitting fuels, engines and vehicles. Parallel to technological developments for vehicles, demand for transportation also has to be managed and reduced to a certain extent by the modification of traffic towards non-pollutant or low-pollutant emitting modes such as public transport, rail systems, bicycles or walk in urban regions.

A significant change in passenger transport systems is required to reduce transport related energy consumption using vehicles with fuel efficient engines compared to conventional systems. In the long run, hybrid-electric vehicles and electric motors powered by fuel cells are the technological solutions to present problems, but short term achievements would require the development of infrastructure for more efficient public transportation systems.

Greater use of non-motorised means of short distance trips with supporting infrastructure is also of vital importance for both low GHG emissions and sustainable transport.

The use of information technology for communication would also reduce requirement for personal transportation in order to limit energy consumption and GHG emissions.

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NATIONAL TRANSPORT REHABILITATION IN TURKEY

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1. Introduction

The objective of this study is to investigate how to reduce greenhouse gases (GHGs) from ground transport in Turkey through the promotion of a long-term modal shift to more efficient and less polluting forms of transport. The transport sector contributes to rising GHG emissions in the form of CO_2, CH_4, N_2O and gases responsible for the formation of O_3, such as NO_x and the VOCs. As carbon dioxide emissions are directly linked to fossil-fuel use in transport, GHGs can be reduced as less energy-intensive and zero-emission modes of transport are promoted.

Based on the methodology and emission rates prepared by Soruşbay and Ergeneman (2006), detailed analysis of the projections for short and long term scenarios and the resulted emissions estimations are given in this report.

In 2004, 98 % of the passenger transportation and almost 100 % of the freight transportation were carried by road and rail transport in Turkey. Therefore, GHG emissions estimates were made for road and rail transport in the period between 2005 and 2020. Two separate approaches were used to estimate the emissions from road transport:

(i) Estimating emissions based on the fleet size of motor vehicles (Fleet-based estimation).

(ii) Estimating emissions based on traffic demand considering modal shift from road to rail (Demand-based estimation).

2. Developing Scenarios

Since there is no agreement on how the future will unfold, we assume individual scenarios that have diverging tendencies- one emphasises stronger economic values, the other stronger environmental values; one assumes increasing globalisation, the other increasing regionalisation. In the "conventional worlds" scenario, for instance, society develops gradually from current patterns and dominant tendencies, with development driven primarily by markets as developing countries converge towards the development model of advanced industrial countries.

The "sustainable development" scenarios that project declining emissions are in general characterised by increased co-operation and political participation; many assume that there is strong international agreement on the environment and development in general and climate change in particular. There is improved environmental quality and equity. Population continues to grow but at slower rates and stabilises at relatively low levels. In most of these scenarios significant developments of energy efficiency, energy conservation, and alternative energy technologies are key to emission reduction.

It is important that emission scenarios consider qualitative aspects that are potentially important for future GHG emissions and mitigation policies. One way of incorporating qualitative dimensions into quantitative scenarios is to develop quantitative estimates of key variables based on qualitative description of future worlds.

2.1. Population Projection

With a population of about 73 million and GDP of € 215 billion at current prices, Turkey is among the 20 biggest economies in the world. Furthermore, it is an unsaturated market in almost every category of consumption goods ranging from fast moving consumer goods to high technology products. Its demographic transformation process also contributes to a high growth potential.

The crude fertility rate has decreased relatively fast to a factor nearly 2 and consequently the population growth rate is approaching that of developed countries. While the ratio of the dependent population (including the elderly and children) decreases, the potentially active labour force (15-64 years) is expected to rise from 60% to 69% over the next two decades, accelerating the growth potential of the economy. Considering the favourable demographic transformation, an export driven economy, rapidly developing information society and decreasing budget deficits, potential output growth is likely to be not below 6% from the medium to the long term.

Table 1 and Figure 2 present the population projection made by TURKSTAT for the period between 2005 and 2020.

Table.1 Population projection in Turkey (Source :TURKSTAT, Demographic indicators)

Year	Population	Year	Population
1990	56,473,035	2006	72,974,000
1991	57,606,124	2007	73,875,000
1992	58,739,213	2008	74,766,000
1993	59,872,303	2009	75,643,000
1994	61,005,392	2010	76,505,000
1995	62,138,481	2011	77,340,000
1996	63,271,570	2012	78,156,000
1997	64,404,659	2013	78,957,000
1998	65,537,749	2014	79,746,000
1999	66,670,838	2015	80,524,000
2000	67,803,927	2016	81,304,000
2001	68,365,000	2017	82,072,000
2002	69,302,000	2018	82,828,000
2003	70,231,000	2019	83,571,000
2004	71,152,000	2020	84,301,000
2005	72,065,000		

2.2. Economic Growth Scenarios

Turkey has made a transition to a market economy, particularly in the last two decades. After the introduction of the customs union with EU in 1996, it turns out that the economy has considerable endurance capability in the face of international competition, although certain structural problems remain.

Turkey has been preparing a Pre-Accession Economic Programme, which forms one of the two significant pillars of the Pre-Accession Fiscal Surveillance Procedure that covers the economic reforms required for becoming a full member of the EU; and the economic policies, structural reforms and institutional capacity necessary for accession to Economic and Monetary Union after membership. Turkey has also made progress by reducing its macroeconomic imbalances and should be able to cope with competitive pressure and market forces within the Union provided that it can take further steps towards structural reforms.

In the recent years Turkey's GDP has increased at a higher rate than in nineties with almost 10 % in 2004, 5.9 % in 2003 and 7.8 % in 2002 (Figure 1). In the period between 1970 and 2004, the average annual growth rate was 4.2 %. In this study, a higher growth rate of 6 % is assumed for the period between 2005 and 2020. This is the growth rate assumed in the "central scenario" in the TINA Turkey Project[1]. This scenario is also referred as the "new trend scenario" which is more based on recent trends of the past five years, directly influenced by breaks in trends recently observed in world trade.

[1] *TINA for Turkey, Interim report 2, TINA Turkey joint venture, May 2006.*

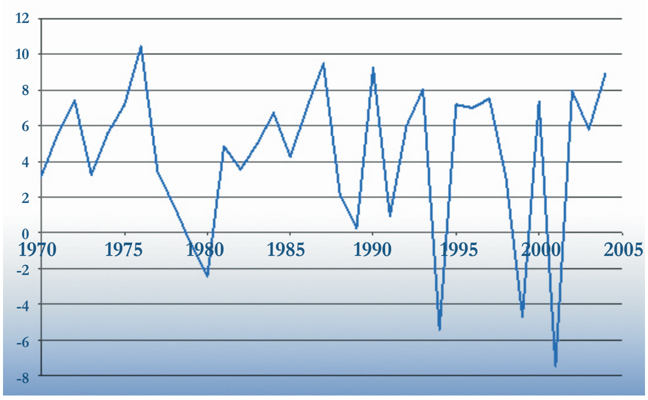

Figure.1 GDP Growth in Turkey (Source: TURKSTAT Economic Indicators)

3. Methodology for Estimating Emissions From Road and Rail Transport

In 2004, 98 % of the passenger transportation and almost 100 % of the freight transportation are carried by road and rail in Turkey. Therefore, GHG emissions estimates were made for road and rail transport in the period between 2005 and 2020, using (1) fleet-based and also (2) demand-based estimation.

For railway transportation, demand-based estimation methodology was used based on the emission factors that were adopted in Soruşbay and Ergeneman (2006).

3.1. Fleet-based Estimation of Emissions from Road Transport

At present, 95% of the passenger transportation and 94 % of the freight transportation are carried by road and thus resulting in considerable GHG emissions in transport sector. There are currently 5.4 million passenger cars on Turkey's roads and the domestic demand for motor vehicles continues to grow unabated. A record 750,000 vehicles were sold in 2004, including 450,000 cars, according to the Turkish Automotive Industry Association. The recent strong economic growth has fueled the sharp increase in private consumption and the accompanying environmental consequences.

Number of motor vehicles in the 1992-2005 period in Turkey is given in Table 2. Vehicle ownership (number of vehicles per 1,000 inhabitants) has risen from 78 in 1992 to 143 in 2005 (Figure 2). Automobile ownership has risen from 37 to 75 in the same period.

In general, there is a strong relationship between the GDP per capita and vehicle ownership (Figure 2).

Regression analyses using the data for the 1992-2005 period, yields the following log-linear equations for automobile and total motor vehicle ownership:

$$\ln (AO) = -23.385 + 1.912 \ln (GDP) \qquad R^2=0.637$$
(-3.91) (4.59)

$$\ln (MO) = -19.943 + 1.718 \ln (GDP) \qquad R^2=0.676$$
(-4.05) (5.00)

where, AO is automobile ownership per 1 000 inhabitants and MO is motor vehicle ownership per 1 000 inhabitants. GDP is per capita domestic product at 1987 prices (YTL). The figures shown in parentheses are the t statistics of the coefficients.

Assuming an average growth rate of 6 % in GDP and considering the population projections given in Table 1, vehicle ownership projections are estimated as shown in Figure 2. Car and motor vehicle ownership in general is projected to increase to 332 and 535 per 1 000 persons in 2020, respectively. As shown in Figure 4, the number of cars in Turkey is estimated to increase by 4.4 times and the number of motor vehicles by 5.2 times in the 2005 – 2020 period. The number of motor vehicles estimated for the 2005-2020 period is shown in Table 3 and Figure 5.

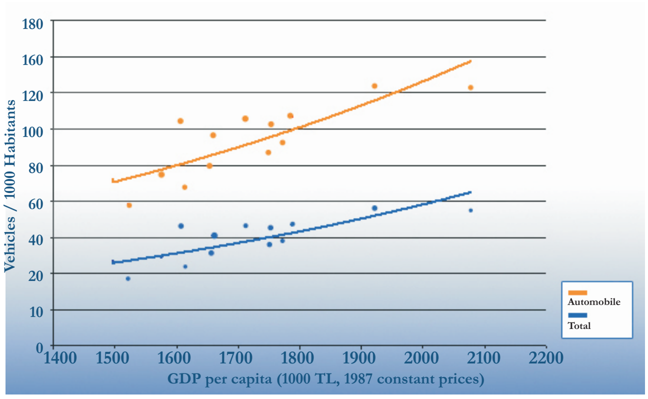

Figure.2 Vehicle ownership vs. GDP per capita in Turkey

Table.2 Number of motor vehicles in Turkey (Source :TUİK, Motor vehicle statistics.)

Year	Total	Automobile	Minibus	Bus	LDV	Truck	Motorcycle	Other	Farm Truck
1992	4,584,717	2,181,388	145,312	75,592	308,180	379,410	655,347	10 908	828,580
1993	5,250,622	2,619,852	159,900	84,254	354,290	406,398	743,320	12 049	870,559
1994	5,606,712	2,861,640	166,424	87,545	374,473	419,374	788,786	12 964	895,506
1995	5,922,859	3,058,511	173,051	90,197	397,743	432,216	819,922	13 691	937,528
1996	6,305,707	3,274,156	182,694	94,978	442,788	453,796	854,150	15 003	988,142
1997	6,863,462	3,570,105	197,057	101,896	529,838	489,071	905,121	16 993	1,053,381
1998	7,371,241	3,838,288	211,495	108,361	626,004	519,749	940,935	19 252	1,107,157
1999	7,758,511	4,072,326	221,683	112,186	692,935	531,690	975,746	20 319	1,131,626
2000	8,320,449	4,422,180	235,885	118,454	794,459	557,295	1,011,284	21 822	1,159,070
2001	8,521,956	4,534,803	239,381	119,306	833,175	562,063	1,031,221	22 939	1,179,068
2002	8,655,170	4,600,140	241,700	120,097	875,381	567,152	1,046,907	23 666	1,180,127
2003	8,903,843	4,700,343	245,394	123,500	973,457	579,010	1,073,415	24 468	1,184,256
2004	10,236,358	5,400,714	318,957	152,380	1,260,009	647,295	1,218,710	27,979	1,210,314
2005	10,283,260	5,421,921	320,294	153,024	1,274,001	648,768	1,224,412	28,063	1,212,777

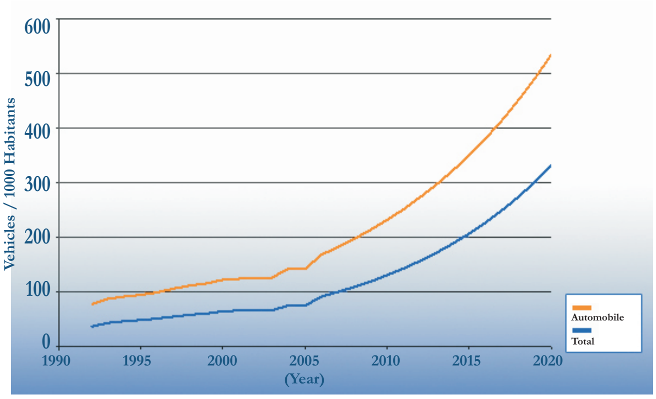

Figure.3 Vehicle ownership projections in Turkey

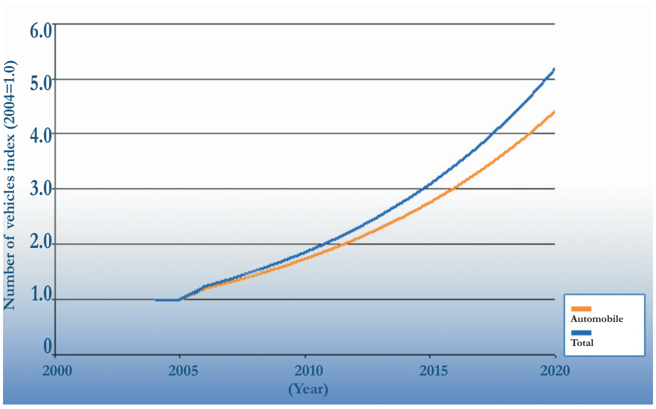

Figure.4 Vehicle ownership growth index in the 2005-2020 period

As explained in Soruşbay and Ergeneman (2006), the fuel based approach was used to estimate the GHG emissions from the road vehicles in the future. The emission factors used in the IPCC Tier 1 approach are based on the heat content of the fuel used, the fraction of the carbon in the fuel that is oxidised during the combustion process and carbon content coefficients. Combustion efficiency is assumed to be 99 % in most cases, depending on the fuel used. The average annual distance travelled by each vehicle category were as given in Sorubbay and Ergeneman (2006).

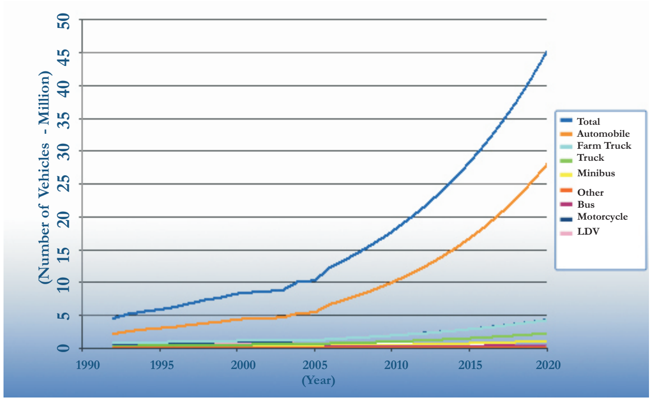

Figure.5 Motor vehicle fleet projections in Turkey

Estimations for annual vehicle-km for each vehicle category in the 2005 – 2020 period are given in Table 4. GHG emissions estimations in the same period are given in Table 5.

It should be noted that older vehicles or those with antiquated or malfunctioning pollution controls are a major source of emissions in Turkey for a variety of reasons:

(i) Climates that allow vehicle chassis to last for many years without rusting, and

(ii) Economic conditions that increase the value of substandard vehicles sufficiently so as to keep them on the road longer

Turkey has a large population of older, uncontrolled vehicles that make a disproportionate contribution to air pollution. 1/3 of trucks in Turkey are over 20 years old (Table 6).

Table.4 Projections for vehicle-km in Turkey

Year	Vehicle-Km (Million)					
	Automobile	Minibus	Bus	LDV	Truck	Motorcycle
2005	66,556	6,406	10,253	24,843	22,707	2,449
2010	121,355	10,228	16,369	39,393	36,323	3,908
2015	190,484	15,260	24,422	58,775	54,194	5,831
2020	299,326	22,641	36,236	87,206	80,410	8,651

Table.5 Estimation of emissions from motor vehicle fleet in Turkey

Year	CO2 (Mt)	NOx (t)	CH4 (t)	NMVOC (t)	CO (t)	N2O (t)
2005	49.82	501,838	4,790.34	361,477.48	2,245,411.04	2,350.26
2010	82.47	811,014	7,970.18	582,839.28	3,596,770.49	4,328.50
2015	123.60	1,149,906	11,200.04	722,197.33	4,232,315.31	8,317.68
2020	184.55	1,608,295	15,505.68	830,523.60	4,424,120.69	15,441.73

Table.3 Motor vehicles projections in Turkey

Year	Total	Automobile	Minibus	Bus	LDV	Truck	Motorcycle	Other	Farm Truck
2005	10,283,260	5,421,921	320,294	153,024	1,274,001	648,768	1,224,412	28,063	1,212,777
2006	12,325,378	6,705,324	370,696	177,098	1,464,400	752,295	1,416,402	32,518	1,406,644
2007	13,503,746	7,412,271	401,791	191,954	1,587,237	815,399	1,535,212	35,245	1,524,636
2008	14,797,774	8,195,865	435,459	208,038	1,720,239	883,726	1,663,856	38,199	1,652,393
2009	16,219,615	9,065,001	471,915	225,455	1,864,256	957,710	1,803,152	41,397	1,790,729
2010	17,782,294	10,029,328	511,382	244,310	2,020,167	1,037,805	1,953,952	44,859	1,940,491
2011	19,502,196	11,101,060	554,135	264,735	2,189,058	1,124,569	2,117,308	48,609	2,102,721
2012	21,393,972	12,291,350	600,405	286,840	2,371,843	1,218,469	2,294,101	52,668	2,278,297
2013	23,474,297	13,612,979	650,448	310,748	2,569,534	1,320,027	2,485,313	57,058	2,468,191
2014	25,761,599	15,080,201	704,540	336,590	2,783,219	1,429,802	2,691,994	61,802	2,673,448
2015	28,276,534	16,709,137	762,980	364,510	3,014,081	1,548,401	2,915,289	66,929	2,895,205
2016	31,038,518	18,515,190	826,033	394,633	3,263,165	1,676,362	3,156,209	72,460	3,134,465
2017	34,076,116	20,520,914	894,095	427,149	3,532,038	1,814,487	3,416,269	78,430	3,392,733
2018	37,417,237	22,748,739	967,528	462,231	3,822,126	1,963,512	3,696,849	84,872	3,671,380
2019	41,092,999	25,223,921	1,046,718	500,064	4,134,957	2,124,221	3,999,427	91,818	3,971,874
2020	45,137,419	27,974,369	1,132,067	540,839	4,472,124	2,297,431	4,325,542	99,305	4,295,742

Table.6 Age distribution of motor vehicles (%)

Age (Years)	Automobil	Minibus	Bus	Small Truck	Truck	Total
>25	7.1	10.8	12.5	14.2	22.6	9.8
21-25	3.5	4.9	7.3	3.2	10.7	4.2
16-20	9.8	9.6	10.4	4.4	11.3	9.0
11-15	26.7	17.4	21.5	10.6	15.1	22.6
6-10	24.8	28.9	21.4	25.1	22.2	24.8
0-5	28.1	28.4	26.9	42.5	18.1	29.6
Total	100.0	100.0	100.0	100.0	100.0	100.0

(*) As of January 31, 2005.

Several strategies can be considereded to address the problem of older vehicles. These fall into the following major categories:

(i) Inspection and maintenance
(ii) Retrofit
(iii) Accelerated retirement (Scrappage)
(iv) Import restrictions
(v) Alternative fuel conversions

Soruşbay and Ergeneman (2006) estimate that removal of about 320,000 old vehicles from registers by providing tax advantages to consumers in 2003 and 2004 has resulted in 4.87 % reduction of CO_2 emission.

3.2. Demand-Based Estimation of Emissions from Road to Rail

The cities in Turkey are linked by a good network of highways about 65,000 km long. Since 1950, a distinct shift occurred in transport investment which has favoured the development of roads and, to a certain extent, harbours. As a part of the Trans European Motorway (TEM) project, 1,851 km of motorways have been built in the last two decades. Investments to improve the highway system resulted in highways dominating cargo and passenger transport.

The disproportion between the development of roads and railways, i.e. under-investment in railways has resulted in continued inadequacy of rail transport and in a dramatic decline of rail traffic.

Transport demand in Turkey has grown significantly over the past five decades. Overall, passenger demand (as measured by passenger-kilometers) has grown at an annual rate of 4.20 % between 1970 and 2004, whilst freight demand (as measured by ton-kilometers) has grown at an annual rate of 5.31 %. Since 1950s, rail market shares have continuously declined. It is not likely that much new traffic can be attracted to railroads without significant investment in new and expensive infrastructure, or major changes in railway service.

In 2005, road transport represented 94 % of the freight transport market and 95 % of passenger transport market in Turkey. Although traffic market shares of the Turkish State Railways (TCDD) have declined significantly, overall railway traffic has remained more or less constant.

Strategic and demand based solutions generally rely on influencing behaviour, and can use a wide variety of methods to do so. Data are often not complete enough to allow the estimation of the cost-effectiveness of these "non-technical" type measures. However, in countries like Turkey mass transport modes and demand management strategies are essential to complement technological solutions for three factors:

a) Lack of leverage in global vehicle markets to influence the development of appropriate transport technologies,

b) Relatively large stocks of older, more polluting vehicles combined with slower stock turnover,

c) Inability to keep pace with rapid motorisation in the provision of infrastructure.

Transport statistics clearly indicate a steady upward trend in both passenger and freight demand. While in the past demand has been strongly linked to growth in GDP and income, it is important to look at this relationship more closely. Gaining a better understanding of the drivers of transport demand allows ways in which it may be possible to decouple transport growth from income growth. In this respect "non-technical" strategic and demand based solutions are likely to be important in the longer term.

The main increase in passenger vehicle kilometres seems to arise not from people travelling more often, but from travelling further and with greater use of private car. Recent research in some European countries suggests that half of freight traffic growth can be explained by economic growth, and that the remainder appears to be due to changes in spatial geography and logistic systems. For example, the concentration of production and distribution facilities, expansion in market both at a national and European level, and the shift away from bulk commodities which are usually transported over short distances to higher value commodities requiring longer hauls.

In this study, the estimation of the emissions based on the future traffic demand was carried out through the following steps:

a) Analysing the relationship between the total transport demand and the GDP growth based on the data of the 1970 – 2004 period.

b) Estimating future transport demand by road and rail.

c) Analysing the relationship between the transport demand and the emissions from road and rail transport.

d) Estimating the emissions from road and rail transport in the 2005 – 2020 period.

3.2.1. Relationship etween Transport Demand and GDP Growth in Turkey

In the 1970 – 2004 period, transport demand has been strongly linked to growth in GDP in Turkey. The passenger demand (as measured by passenger-kilometers) has grown at an annual rate of 4.20 % and the freight demand (as measured by ton-kilometers) at an annual rate of 5.31 %, whilst GDP (as measured at 1987 constant prices) has grown at an annual rate of 4.20 %. Figure 9 shows the log-linear type of relationship between the economic growth and transport demand in Turkey in this period.

Regression analyses carried out with the data in the 1970-2004 period yields the following log-linear equations for passenger and freight transport demand:

$$\ln(PKM) = -7.239 + 1.0437 \ln(GDP) \qquad R^2=0.968$$
(-12.08) (31.48)

$$\ln(TKM) = -15.799 + 1.493 \ln(GDP) \qquad R^2=0.967$$
(-18.12) (30.95)

where, PKM is passenger-km; TKM is ton-km; and GDP is income per capita at 1987 prices (YTL). The values in parentheses are the t statistics of the coefficients.

3.2.2. Future Transport Demand by Road and Rail

The Turkish railway network is relatively under-developed. The infrastructure and management lags behind the latest technology and management techniques. The existing railway network is concentrated on a few major routes. This makes transportation by rail possible only in certain areas and between certain cities. The railway network is old and has suffered from under investment for decades. Investment in this sector has been aimed at improving standards so that rail transport can become a competitive alternative to road and air transport.

One of the primary objectives of the Turkish transport policy is restructuring the railways. An ambitious Rail Transport Action Plan for the restructuring of the railway sector by 2008 was adopted. In this plan, special attention is paid to the restructuring of the entire railway sector, including the reorganisation of the railway administration. Designed to keep pace with EU policies, the plan sets forth the provision of autonomy to the TCDD Administration, organisation of the administration on the basis of units to render transport services more efficiently, elimination of the vertical structure, and access to the private sector. Subsidies paid to railway operations need to be defined in terms of a public sector obligation and covered by a public sector contract. Particular attention will also be given to the rapid modernisation of the rail infrastructure.

In 2005, rail market shares were 3 % and 6 % for passenger and freight transport respectively. In this study, it is assumed that rail transport will increase its market share as shown in Table 7.

Assuming an average annual GDP growth of 6 % in the future and modal shifts from road to rail given in Table 7, passenger and freight transport demand by road and rail were estimated and shown in Table 8.

Table.7 Assumed market shares of road and rail transport in Turkey (2010-2020)

Year	Railways		Highways	
	Passenger-Km	Ton-Km	Passenger-Km	Ton-Km
2010	0.05	0.08	0.92	0.90
2015	0.07	0.12	0.89	0.85
2020	0.09	0.15	0.86	0.80

Table.8 Estimated transport demand by road and rail

Year	Passenger-Km (Million)			Ton-Km (Million)		
	Railways	Highways	Total	Railways	Highways	Total
1990	6,410	134,991	142,736	8,031	65,710	81,082
1995	5,797	155,202	163,726	8,632	112,515	121,654
2000	5,833	185,681	195,099	9,895	161,552	179,657
2005	6,972	232,060	243,323	11,712	195,080	207,192
2010	16,490	303,409	329,792	21,135	237,764	264,182
2015	29,128	370,339	416,111	48,792	345,610	406,600
2020	50,704	484,505	563,378	93,869	500,634	625,793

3.2.3. Relationship Between Emissions and Transport Demand

Emissions from road transport in the 1990 – 2004 period were estimated in Soruşbay and Ergeneman (2006) using the emission factors used in the IPCC Tier 1 approach.

Table 9 and 10 show the transport demand (as measured by passenger-km and ton-m) and the emissions from road and rail transport, respectively.

Using the data given of Tables 9 and 10, regression analyses were carried out to determine the relationship between emissions and transport demand for road transport. The results of the regression analyses are shown in Table 11.

Table.9 Transport demand and emissions from road transport

Year	Passenger-Km (M)	Ton-Km (M)	CO2 (Mt)	NOx (t)	CH4 (t)	NMVOC (t)	CO (t)	N2O (t)
1990	134,991	65,710	22.71	238,413.03	3,233.85	208,090.27	1,499,833.46	796.34
1991	131,029	61,969	21.45	223,729.57	3,135.67	205,089.93	1,452,805.36	748.01
1992	142,172	67,704	21.98	227,037.64	3,426.78	230,268.23	1,617,451.86	742.42
1993	146,029	97,843	26.55	273,186.96	4,091.63	274,174.06	1,937,961.51	904.71
1994	140,743	95,020	28.39	286,607.94	4,948.39	340,032.55	2,420,536.79	904.08
1995	155,202	112,515	30.40	306,766.78	5,434.96	373,918.54	2,588,099.30	971.49
1996	167,871	135,781	32.78	332,834.80	5,850.09	398,825.36	2,697,910.83	1,068.58
1997	180,967	139,789	30.78	306,657.93	5,794.54	401,689.78	2,730,020.14	979.60
1998	186,159	152,210	28.84	283,448.78	5,735.12	400,925.03	2,707,076.67	912.35
1999	175,236	150,947	31.55	313,718.08	5,727.33	391,659.80	2,570,564.72	1,092.11
2000	185,681	161,552	32.28	327,744.42	5,127.33	335,095.29	2,189,338.57	1,208.70
2001	168,211	151,421	32.26	331,834.28	4,725.42	299,961.01	1,918,439.95	1,265.10
2002	163,327	150,912	33.63	348,251.84	4,680.01	290,427.08	1,851,551.89	1,366.29
2003	164,311	152,163	35.80	368,445.50	4,621.52	280,537.62	1,749,873.25	1,539.98
2004	174,312	156,853	39.09	394,434.76	4,648.26	272,841.25	1,645,523.87	1,905.15

Table.10 Transport demand and emissions from rail transport

Year	Passenger-Km (M)	Ton-Km (M)	Fuel (Lt)	Fuel (Ton)	CO2 (Mt)	NOx (t)	CH4 (t)	NMVOC (t)	CO (t)	N2O (t)
1990	6,410	8,031	190,661,176	162,062	0.517	12,041	40.5	891	4,230	13.0
1991	6,048	8,093	194,117,647	165,000	0.526	12,259	41.2	907	4,306	13.2
1992	6,259	8,383	183,529,412	156,000	0.497	11,591	39.0	858	4,072	12.5
1993	7,147	8,511	215,294,118	183,000	0.583	13,597	45.8	1,007	4,776	14.6
1994	6,335	8,338	228,235,294	194,000	0.618	14,414	48.5	1,067	5,063	15.5
1995	5,797	8,632	228,235,294	194,000	0.618	14,414	48.5	1,067	5,063	15.5
1996	5,229	9,018	233,294,118	198,300	0.632	14,734	49.6	1,091	5,176	15.9
1997	5,840	9,716	232,941,176	198,000	0.631	14,711	49.5	1,089	5,168	15.8
1998	6,160	8,466	235,294,118	200,000	0.638	14,860	50.0	1,100	5,220	16.0
1999	6,146	8,446	235,294,118	200,000	0.638	14,860	50.0	1,100	5,220	16.0
2000	5,833	9,895	176,295,000	149,851	0.478	11,134	37.5	824	3,911	12.0
2001	5,568	7,562	139,288,000	118,395	0.377	8,797	29.6	651	3,090	9.5
2002	5,204	7,224	140,053,000	119,045	0.380	8,845	29.8	655	3,107	9.5
2003	5,878	8,669	145,614,000	123,772	0.395	9,196	30.9	681	3,230	9.9
2004	5,237	9,417	138,116,000	117,399	0.374	8,723	29.3	646	3,064	9.4

Table.11 Results of regression analysis of emissions vs. transport demand for road transport

	Coefficients					
	CO2 (Mt)	NOx (t)	CH4 (t)	NMVOC (t)	CO (t)	N2O (t)
PKM	0.00012355	1.310819857	0.023804436	1.758322839	14.40027381	0.0018285
TKM	7.9785E-05	0.739819474	0.007415774	0.252770134	-1.685239549	0.0063967
R Square	0.991	0.989	0.987	0.976	0.969	0.961
Standard Error	3.09	34,076.50	589.87	53,034.10	405,521.36	240.73

PKM: Passenger-Km (Million), TKM: Ton-Km (Million)

Similarly, a linear regression analysis was carried out to determine a relationship between the fuel consumption (in tons) and transport demand in railways and the following equation was obtained:

Fuel (ton) = 18.898 PKM + 6.236 TKM R^2=0.972
(1.76)   (0.84)

where, PKM is passenger-km by rail (millions); and TKM is ton-km by rail (millions). The values in parenthesis are the t statistics of the coefficients.

3.2.4. Results of Demand-Based Estimations of Emissions from Road and Rail Transport

For each emission category, emissions from road transport were calculated by multiplying the future transport demand with the coefficients given in Table 11. In order to estimate the emissions from rail transport, the emission factors given in Soruþbay and Ergeneman (2006) were multiplied by the fuel consumptions obtained from the linear regrassion equation of Section 3.2.3. Assuming an annual GDP growth of 6 % in the 2005-2020 period, Table 12 summarises the total emissions from road and rail transport estimated by demand-based approach.

Table.12 Results of demand-based estimates of emissions

Year	CO2 (Mt)	NOx (t)	CH4 (t)	NMVOC (t)	CO (t)	N2O (t)
2005	44.89	463,729.40	7,021.93	458,473.43	3,018,316.98	1,688.56
2010	57.87	606,562.57	9,096.53	596,028.90	3,980,051.72	2,111.15
2015	76.05	804,642.66	11,592.35	743,236.12	4,772,853.49	2,956.28
2020	104.72	1,120,165.56	15,631.85	986,951.21	6,173,602.16	4,211.78

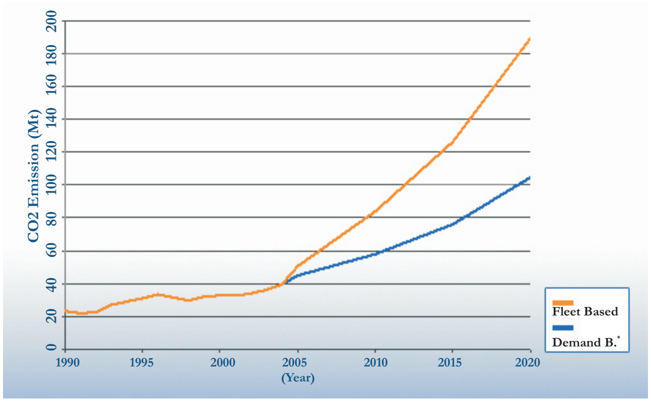

Figure.6 Estimated CO_2 emissions from road and rail   * *Demand based*

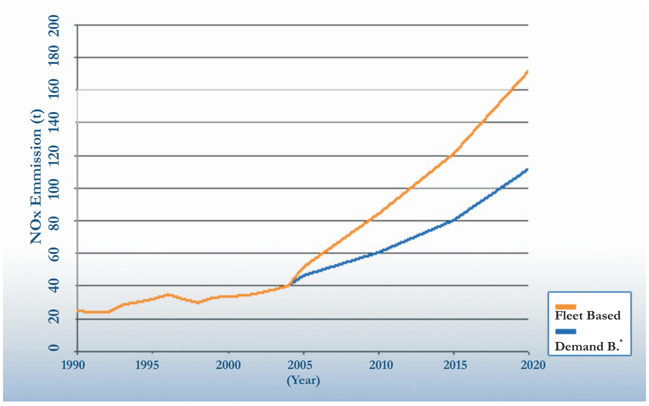

Figure.7 Estimated NO_x emissions from road and rail   * *Demand based*

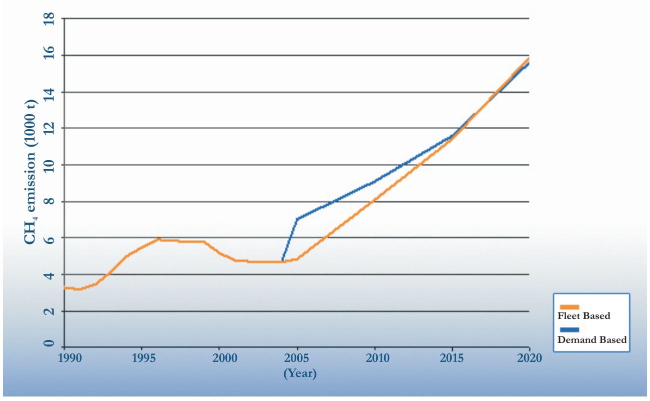

Figure.8 Estimated CH_4 emissions from road and rail

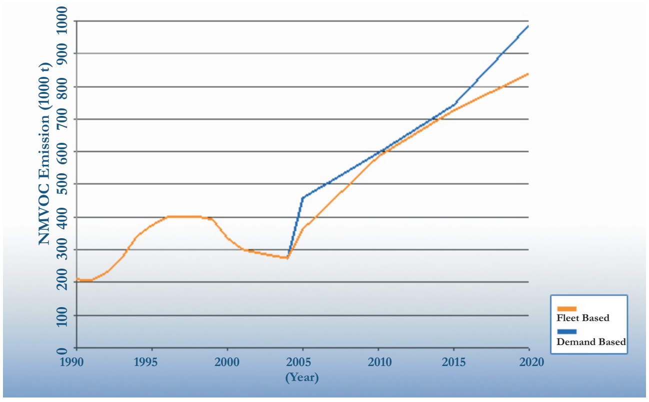

Figure.9 Estimated NMVOC emissions from road and rail

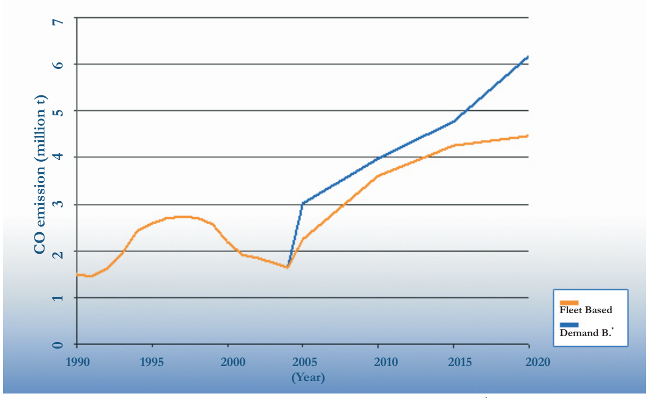

Figure.10 Estimated CO emissions from road and rail   * *Demand based*

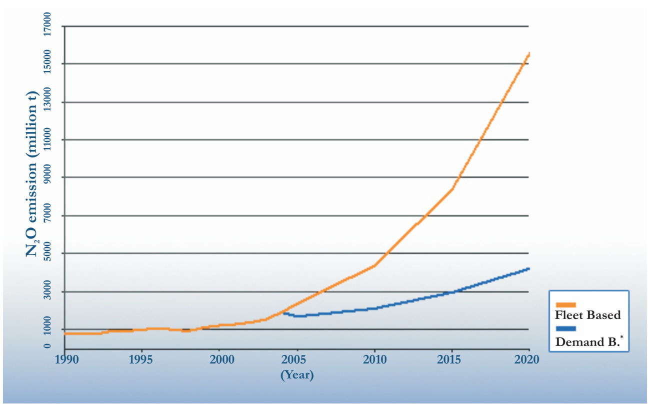

Figure.11 Estimated N_2O emissions from road and rail   * *Demand based*

The resulting emissions estimated with fleet-based and demand-based approaches are shown in Figure 6 through 11. The differences between the fleet-based and demand-based emissions are due to a number of reasons:

(i) The fleet-based approach assumes average annual kilometres travelled for each vehicle category estimated from the fuel consumptions in the past. As pointed out by Soruşbay and Ergeneman (2006), a considerable amount of fuel is smuggled into Turkey and this leads to uncertainties in estimating the average annual kilometres. It is estimated that diesel fuel smuggled into the country amounted up to 1.5 M ton in 2003 and 0.9 M ton in 2004. Similarly, 1 M ton of gasoline annually is estimated to be smuggled into Turkey in 2003 and 2004.

(ii) Even a moderate modal shift from road to rail is estimated to reduce total emissions by 9-12 %. In this study, it is assumed that road transport will lose its passenger market by 9 % and freight market by 14 % in the period between 2005 and 2020. In 2020, these modal shifts are estimated to reduce total emissions by 9 % for CO_2, 5 % for NO_x, 9.6 % for CH_4, 10 % for NMVOC, 8.6 % for CO and 12.1 % for N_2O.

(iii) Finally, it should be noted that the estimated elasticities of output variables of the transportation system (such as motor vehicle fleet size, road vehicle-km travelled, passenger-km and ton-km) with respect to the GDP growth as well as the estimated elasticities of the emissions with respect to transportation system outputs are the main determinants of the resulted emissions estimations. Table 13 summarizes the changes in the emissions estimated with two approaches with respect to changes in the main variables used.

Table.13 Changes in variables and emissions for 2005-2020

Variables	(%)	
GDP	139.7	
Number of Motor Vehicles	338.9	
Road Vehicle-Km	301.2	
Passenger-Km (*)	131.5	
Ton-Km (*)	202.0	
Emissions	Fleet-Based	Demand-Based
CO2	270.5	133.3
NOx	220.5	141.6
CH4	223.7	122.6
NMVOC	129.8	115.3
CO2	97.0	104.5
N2O	557.0	149.4

4. Conclusions

There are three main ways in which GHG emissions from transport can be reduced:

(i) Operational – reducing energy use and emissions per vehicle-km driven.
(ii) Strategic – optimisation of the vehicle use, reducing total vehicle-km per passenger-km or per tonne-km.
(iii) Demand related – reducing the overall demand (passenger-km or tonne-km) for travel.

A number of policy instrumentss are available for implementing measures in these three categories, including:

(i) Pricing policies and incentives
(ii) Taxation
(iii) Regulation
(iv) Infrastructure
(v) Information and public awareness initiatives
(vi) Voluntary agreements
(vii) Institutional frameworks

Transport policy in Turkey is at a crossroads. The future depends on using road transport rationally, switching from road to rail (and water) without losing competitiveness, efficiency, speed or comfort, making more journeys that involve a mix of different modes, and reducing transport-related pollution.

The transportation sector can meet the requirements of sustainable development only under certain conditions. There must be:

(i) Political will and determination to solve the problems together;

(ii) A new approach to urban transport which provides scope for a rational use of private cars;

(iii) Improvements in service quality to offset the rising cost of mobility;

(iv) An adequate way to finance infrastructure and eliminate bottlenecks;

(v) Coherence between the EU's transport policy and other key policies, such as economic and environmental, fiscal, social and budgetary policies, and town-and-country planning.

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Part III:

SOCIO-ECONOMIC DIMENSIONS

Cost-Benefit Analysis and Macro-Economic Projections

A GENERAL EQUILIBRIUM INVESTIGATION OF THE ECONOMIC EVALUATION OF SECTORAL EMISSION POLICIES FOR CLIMATE CHANGE[1]

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Research on environmental abatement has intensified on a global scale as evidence on the costs of global warming continues to accumulate. A special report that appeared in the Financial Times (31 October, 2006), for instance, underlines that "releasing 550 parts per million (ppm) of CO_2 in the earth's atmosphere would incur a high probability of raising global temperatures by more than 2^{0}C above the pre-industrial levels", —an upper limit which is regarded as the safety zone for our planet's climate. The analytics of costs and benefits of possible effective action to curb climate change have been tackled, in turn, in a recent well-celebrated report by Sir Nicholas Stern [2]. The Stern report argued that efforts to stabilize greenhouse concentrations at between 450 to 550 ppm by 2050 would incur a one-off cost of only 1% of global economic output (equivalent to 651 billion 2006 US$). It also warned that, failure to take immediate action would risk the future of the global economy by shrinking the world output by as much as 5 to 20 percent over the next two centuries. This cost would be due to the likely disruptions to the working people's productivity, due to wide-spread of new forms of bacteria and loss of amenities.

It was mainly against these evidence and findings that the European Union set in late 2006, what can be called as the most ambitious goal for impeding climate change, cutting its greenhouse gas emissions, by 2020, to 20% below the level of 1990. The EU further announced its plans to go further and declared that it would increase its own reduction targets to 30% below the 1990 levels by 2020 as part of its bargaining deal to invite the rest of the developed economies and the developing world to take part with the Kyoto Protocol.

Against this background, Turkish environmental policy is at a crossroad. As part of its attempts towards full membership to the European Union, Turkey is under significant pressure to recognize the conditionalities of the Kyoto Protocol to reduce its CO_2 emissions and other gaseous pollutants over the next six years. Yet, as a newly emerging —developing-market economy, Turkey has not yet achieved stability in its energy utilization and gaseous emissions either as a ratio to its GDP or at a per capita level, and is cited among the 25 countries that display fastest rate of growth in industrial use of energy sources (OECD (2004)). Turkish Statistical Institute (TURKSTAT) data indicate, for instance, that on a per capita basis, consumption of electricity power in Turkey has increased by six-folds from 1980 to 2005. TURKSTAT estimates that aggregate CO_2 emissions from fossil burning that stand at 223.4 Gg as of 2004, will reach to 343 Gg by 2010 and to 615 Gg by 2020. This suggests a secular rise of the ratio of the total CO_2 emissions to GDP from 0.632 million tons/billion TRY in 2005 to 0.689 million tons/billion TRY in 2020.

Mainly because of these instabilities, Turkey's global standing in terms of its international abatement requirements is also a matter of controversy, as it is the only country which appears in the so-called Annex-I list of the Rio Summit of the United Nations and yet an official target for CO_2 emission reductions has still not been established. Thus, as part of its accession negotiations with the EU, Turkey will likely to face significant pressures to introduce its national plan on climate change along with specific emission targets and the associated abatement policies. The current arsenal of Turkish environmental policy instruments is mostly limited to energy taxes, environmental impact assessments, and pollution penalties.

Yet, it is a clearly recognized fact that these instruments will not suffice under a more active environmental policy design and will need to be expanded to include other forms of policy measures such as additional pollution taxes, emission trading and permits, and abatement investments towards reduced energy intensities. However, given the current lack of an adequate quantitative modeling paradigm for environmental policy analysis in Turkey, the effectiveness of such policy interventions and their economic impacts are not well-known. Hence, there is a strong need for the construction and utilization of analytical models for environmental policy analysis [3].

This paper attempts to fill this gap and aims to guide policy makers to respond with additional measures that may include a broad, market-based incentives designed to accelerate technology development and deployment in Turkey. Its main objective is an analytical attempt to enable Turkey to integrate sustainable development principles into national development planning and implementation of environmental policy objectives both at the macro economic and sectoral levels. To this end, we propose to build a dynamic, multi-sectoral macroeconomic model in the tradition of computable general equilibrium (CGE) paradigm, to study issues of environmental and macroeconomic policy interactions over both the commodity and the factor markets, and the impact of various policies on the environment and on abatement.

1. Key Environmental Indicators of Turkey

In this paper we focus mainly on CO_2 emissions as the key indicator of environmental pollution. Turkey displays a mid-score in its emission coefficients in comparison to the world and the OECD averages. By 2002, with a per capita CO_2 emissions of 2.8 tons, Turkey lies significantly below the OECD average of 11.0 tons and ranks below the world average of 3.9 tons per capita. In 1990 these values were, 2.3 tons for Turkey, 10.6 tons for the OECD and 4.0 tons for the world, respectively.

Turkish emissions are less robust when the comparison is done with respect to per $ GDP. In 2002 Turkish CO_2 emissions per $ GDP (measured in fixed 1995 prices) was 0.94 kg. The same ratio was 0.44 for the OECD and the world average was 0.68. As compared to the 1990 values, both the world and the OECD averages on CO_2 emissions per $ GDP were observed to fall, and for Turkey there had been a slight increase from 0.89 to 0.94.

The TURKSTAT data indicate that aggregate CO_2 emissions from fossil burning stand at 223.4 Gg as of 2004. TURKSTAT estimates that aggregate CO_2 emissions from energy production will reach to 343 Gg by 2010 and to 615 Gg by 2020. According to data the significant share of CO_2 emissions originate from electricity production. On a per capita basis, consumption of electricity in Turkey has increased by 6-folds from 1980 to 2005, and is expected to increase to 400 kWh per person by 2010.

[1] Author names are in alphabetical order and do not necessarily indicate authorship seigniority. Project support for this study was provided by the Government of Turkey and the United Nations Development Program on Economic Evaluation for Policy Making under the UNDP-GEF Project: "Enabling Activities For The Preparation Of Turkey's Initial National Communication To The UNFCCC" prepared for UNDP and the Ministry of Environment and Forestry, Republic of Turkey. The authors gratefully acknowledge the diligent research assistance of Bengisu Vural and Çağacan Değer, and the invaluable suggestions provided by Yasemin Örücü, Katalin Zaim and by the "Climate Change Team" of the Ministry, headed by Ms. Günay Apak. The views and policy recommendations expressed in the paper are solely those of the authors' and by no means reflect the institutions and the governing bodies stated above. All usual caveats apply.

[2] "The Economics of Climate Change", available on line at: www.hm-treasury.gov.uk

[3] Building models for environmental policy analysis, although scarce for Turkey, is quite a common application in literature. Goulder and Pizer (2006) provide a brief survey of research on economics of climate change, including theoretical insights and empirical findings to offer guidance to policy makers. Adkins and Garbaccio (1999) give a bibliography of only computable general equilibrium model applications to environmental issues.

With increased production capacity and increased consumption demand, Turkish energy intensities are projected to rise. This fact is openly exposed in the country's growing reliance on electricity generation. Gross electricity generation is observed to almost double from 86,247 GWh in 1995 to 149,982 GWh in 2004. This rapid expansion gives an annual average rate of growth of 7.2% over the mentioned period [4].

The sectoral breakdown of energy consumption and primary resource production indicates the growing national imbalances as the domestically supplied share of total energy demand has continuously fallen from 48.1% in 1990 to 27.8% in 2004. All these reveal a sustained domestic deficit, given the expectations of a very significant rise in final energy demand in the next decade. The Ministry of Energy and Natural Resources (MENR) estimates indicate that total energy demand in Turkey will reach to 135,302 thousand TOE and per capita energy will rise from 1,276 kgpe in 2005, to 1,663 kgpe in 2013. These broad shifts underscore that Turkey has not yet stabilized its energy demand, and pressures of a newly industrialized economy continues to be felt [5].

Given the limited substitution possibilities for energy use and the unstable/dynamic character of the production activities, it becomes hard to offer viable guidelines on the available menu of abatement policies.

2. The Model

Given the above overview of the economic and political realm, we now develop our analytical CGE model for Turkey to study issues of environmental abatement and its economic impacts. Although there is a variety of CGE modeling exercises for Turkey, environmental CGE applications is relatively new and scarce. Roe and Yeldan (1996), Boratav, Türel and Yeldan (1996), Şahin (2001) and Kumbaroğlu (2003) are among the few contributions in this respect.

The model that we present here should be considered as a first step to establish a "base-path" over 2006-2020 against which the socio-economic impacts of alternative policy scenarios are to be investigated. "Dynamics" into the model is integrated via "exogenous" updating of the static model into a medium-run of fifteen years using estimates on average population growth, investment behavior on the part of both private and public sectors, and total factor productivity (TFP) growth.

[4] Data suggest network losses of 17% on the average annually. This leaves the country with net consumption of 111,766 Gwh in 2003 and 118,050 GWh in 2004.

The supply-side of the economy is modeled as ten aggregate sectors. In line with our focus on environmental policy evaluation, the disaggregation scheme of the overall economy develops into the energy sectors and critical sectors of GHG pollutions in detail. It thus, aggregates a large number of other activities that, although being far more important contributors to total gross output, are not germane to the climate problem. The sectors that we specify are: Agricultural production (AG); Coal Mining (CO); Petroleum and Gas (PG); Refined Petroleum (RP); Electricity Production (EL); Cement Production (CE); Paper Production (PA); Iron and Steel Production (IS); Transportation (TR); and a composite of remaining manufacturing, services and primary industries sectors of the economy (OE). Labor, capital and a composite of primary energy inputs, electricity, petroleum and gas and coal, together with intermediate inputs comprise the sectorial factors of production.

Production Structure, Factor Endowments

Figure 1 represents the general production structure of the model. Sectoral production is modeled via two-stage production technology where at the second stage, gross output is produced through a technology including capital (K), labor (L), intermediate inputs –excluding primary energy inputs (ID) and primary energy composite (ENG) as factors of production:

$$XS_i = XS_i\,(K_i, L_i, ID_{ji}, ENG_i) \quad (1)$$

i = AG, CO, PG, RP, EL, CE, PA, IS, TR, OE
j = AG, RP, CE, PA, IS, TR, OE

[5] The MENR also estimates investment needs for meeting the increased pace of industrialization and needs of new consumption. Accordingly, Turkey will need to invest a total of US$ 233,339 million over 2005-2020. US$ 5,109 million of this sum is expected to be spent over coal exploration and production and US$ 104,765 million (about 43%) is expected to be spent on electricity generation.

[6] Apart from CGE applications, there are also relatively small number of studies that try to fill in the gap of multi-dimensional need for studying energy-environment-economy issues for Turkey. Karakaya and Özçag (2001) analyze a set of economic instruments that may be relevant to use for sustainable development under climate change. Ediger and Huvaz (2006), with the aid of a decomposition analysis provide estimates of sectoral energy usage in Turkish economy. Lise (2006) tries to unfold factors that explain the decomposition of CO_2 emissions between 1980-2003 for Turkey.

[7] In what follows, we provide a bird's-eye overview of the model, and invite the interested reader to contact us directly for further documentation of its full algebraic structure.

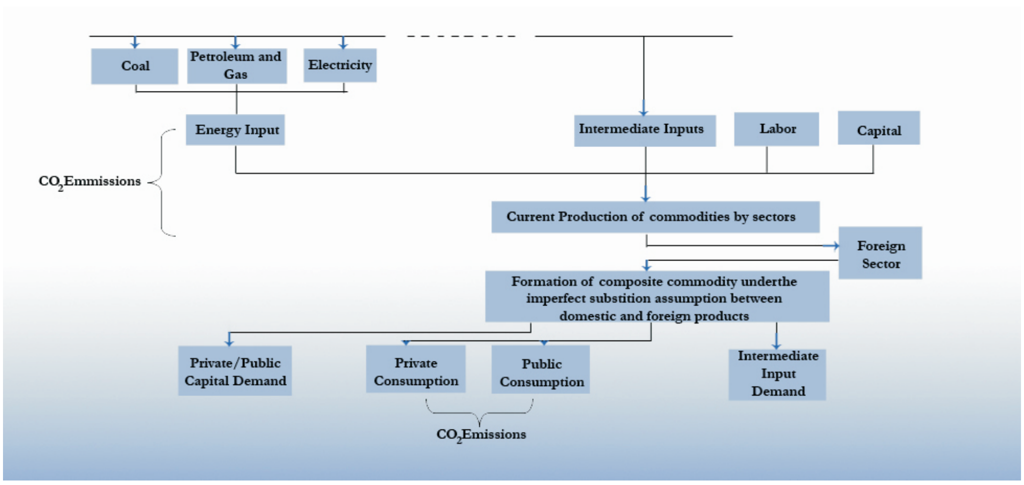

Figure.1 Flows of commodities, factors and emissions in the model.

At the initial stage of the production technology in each sector, the primary energy composite is produced along a constant elasticity of substitution production function using the primary energy inputs, coal, petroleum and gas and electricity:

$$ENG_i = ENG_i\,(ID_{CO,i}, ID_{PG,i}, ID_{EL,i}) \qquad (2)$$

So, in each of the ten sectors of the economy as defined, the primary energy composite, together with other inputs to production (capital, labor, intermediate inputs) contribute to the production of gross domestic output. With the treatment of foreign commodities as an imperfect substitute to domestically produced ones, the final goods markets in the economy is supplied with a representative composite commodity of imports and domestic goods. Final commodities can be demanded for consumption or investment purposes by the private or the public sectors or can be re-circulated back in the production process as intermediate inputs (See Figure 1).

2.2 Environmental Emissions and Taxation

As sketched in Figure 1, three basic sources of CO_2 emissions are distinguished in the model: (i) due to (primary and secondary) energy usage, (ii) due to industrial processes, and (iii) due to energy use of households. Total CO_2 emission in the economy is the sum over from all these sources. Following Gunther et al. (1992), the emissions from industrial processes is regarded to depend on the level of industrial activity, and is regarded proportional to gross output. On the other hand, total emissions due to energy usage originate from two sources: sectoral emissions due to combustion of primary energy fuels (coal and petroleum and gas), and sectoral emissions due to combustion of secondary energy fuels (refined petroleum). Under both sources, the mechanism of emission is dependent on the level of pollutant-emitting inputs (energy input at primary and at secondary levels) in each sector. Final source of emissions in the model is the emissions of CO_2 in the use of energy by households.

Carbon tax is introduced via at rates CO_2tP, CO_2tN_i and CO_2tC_i per tons of carbon dioxide emitted, on production, on intermediate input usage, and on consumption respectively. The revenues are directly added to the revenue pool of the government budget.

2.3 General Equilibrium and Dynamics

The overall model is brought into equilibrium through endogenous adjustments of product prices to clear the commodity markets and balance of payments accounts. With nominal wages being fixed in each period, equilibrium in the labor market is sustained through adjustments of employment.

The model updates the annual values of the exogenously specified variables and the policy variables in an attempt to characterize the 2006-2020 growth trajectory of the economy. In-between periods, first we update the capital stocks with new investment expenditures net of depreciation. Labor endowment is increased by the population growth rate. Similarly, technical factor productivity rates are specified in a Hicks-neutral manner.

3. Calibration and the Base Path for 2003-2020

All policy scenarios are portrayed with respect to a base-run reference scenario. Having calibrated the parameter values, we construct a benchmark economy for the 2003-2020 period, under the following assumptions:

(i) No specific environmental policy action/taxation/quota (business-as-usual environmental policy);
(ii) 2% annual total factor productivity growth rate on average (differentiated for agriculture and industry sectors)
(iii) Exogenously determined foreign capital inflows
(iv) Endogenous (flexible) real exchange rate under the constraint of the current account balance
(v) Exogenously fixed real wage rate
(vi) Fiscal policy in accordance with the announced policy rule of targeted primary surplus.

Figure 2 portrays the likely path of the real gross domestic product under the base-run, the reference model. As observed, the annual real GDP growth rate stays around 6% throughout the 2003-2020 period and the real GDP reaches to a value of 952.7 billion TRY by 2020. Figure 4, on the other hand, illustrates the CO_2 emissions from energy (fuel combustion) as compared to point estimates of the same variable by TURKSTAT. As the figure clearly indicates, the values are comparable to that of TURKSTAT, reported to reach 615.4 mtons of CO_2 by 2020[8]. As the decomposition analysis of Lise (2006) shows, as in any other relatively fast growing economy, the biggest contributor to the rise in CO_2 emissions in Turkey is the expansion of the economy (scale effect). The recent projections of the OECD show that Turkey has an annual growth potential of above 7% (OECD, 2004). UNDP and the World Bank (2003) provide a projection of a six-fold increase in greenhouse gas emissions by 2025 with respect to 1990 level. The study foresees an annual increase of 5.9% in final energy consumption. Given different projections of the growth paths to an extent, we thus observe that the base-run values are well within the ranges reported by TURKSTAT and the international agencies.

Under this growth path of the base-run, given that the production technology parameters are constant, the CO_2 emissions per real GDP also show an increasing trend, by showing almost 10% increase in 2020, compared to 2003 value.

[8] Such a growth path is projected to generate an aggregate CO_2 emission level of 656.4 mtons in 2020.

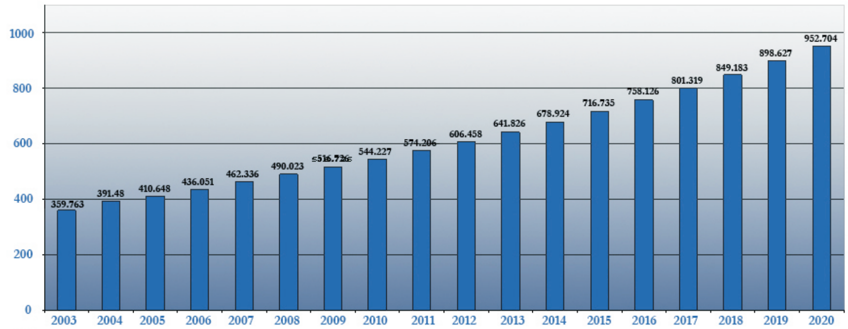

Figure.2 Base-run Real GDP (billion TRY, fixed 2003 prices).

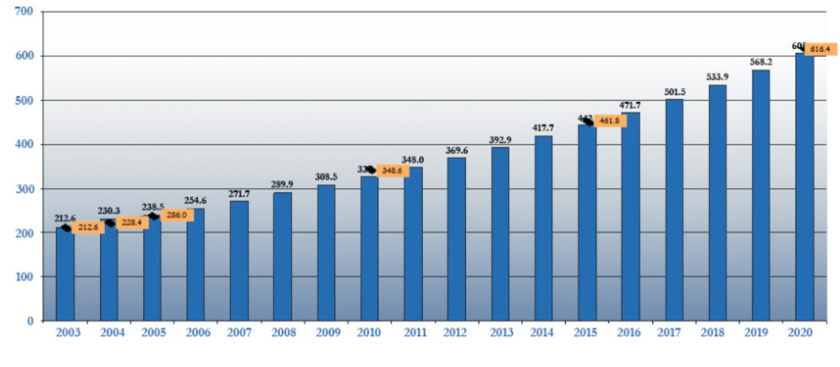

Figure.3 Base Run Total CO_2 Emissions from Energy (million tones)

4. CGE Analysis of Alternative Environmental Policy Scenarios

Now we turn to implementing alternative environmental policy scenarios using our modeling framework. In what follows, we will group our policy interventions into two broad categories: first, we will implement tax and quota based instruments with no additional abatement investments. That is the production-emission structure of the economy will remain as it is. The environmental tax revenues (or subsidy costs) will be administered through the central fiscal budget with no further design on investments to change the energy use and production structure of the economy. Under the second categorization, a more active environmental policy stance will be taken and the implemented policy instruments will be complemented with an active abatement investment policy. The abatement investment will be funded either from environmental tax revenues or from other sources, such as foreign credit and/or national savings.

First we ask the straight question: "what will the economic impacts of maintaining lower CO_2 emissions in the aggregate for the Turkish economy?"

4.1 Quota and Tax Based Instruments with no Additional Abatement Investments

What if one imposes a straightforward, direct quota on the Turkish industries complemented by pollutant fees? What happens to the economic variables of direct quotas on aggregate CO_2 emissions over the 2005-2020 time horizon? Assuming that such quotas are enforced with the accompaniment of pollutant fees, what will be the tax burden? How will this burden affect the producers and investors in their production plans? And consumers? Finally, what will be the net effect of this policy framework on government's fiscal balances, on trade balance, and on unemployment?

These are the questions that we would like to tackle in this first set of scenarios. To this end, we impose a straight aggregate quota of three alternative levels on the 2005-2020 growth path of the Turkish economy: (i) 90% quota; (ii) 80% quota; and (iii) 60% quota. To enforce the quotas, a pollutant fee system is activated.

The fees are to be paid by the polluter pays principle and are to be collected by the fiscal authority directly. No other possible use of such funds for further environmental policy such as abatement investments or any subsidization are envisaged.

Thus, in a nutshell this scenario gives the very basic, direct approach in achieving CO_2 emission targets. The simplicity of this scenario is desirable as its results will offer us the most direct and basic outcomes of a very clear policy instrument to achieve the CO_2 goals in the most straightforward manner. We then build over this simple framework and reach more complex policy packages, yet at each level the outcomes derived from this basic framework will be used as a guideline and a reference point.

As a second scenario set, we focus on energy taxation policy to reduce CO_2 emissions. The model framework admits three sources of energy inputs: coal, petroleum and gas, and electricity. Given the substitution possibilities between energy sources and factor use (capital and labor), the cost minimization procedures will signal the producers to save on energy utilization and thereby reduce CO_2 emitted. We implement the energy taxation policy at two levels: 10% tax and 20% tax.

Table 1 portrays a set of key variables under different quota and tax policies. For instance, if a quota of 90% is envisaged, the rate of growth of GDP is reduced and total GDP falls by 7.1% in comparison to the base run 2020 value. In contrast, if the quota is set at 60% of aggregate emissions of the base path, the GDP of 2020 is observed to fall to 602 billion TRY. This implies a reduction of 36.8%.

Our results indicate that the CO_2 quotas affect the economy in a non-linear fashion. Higher rates of CO_2 restrictions have an increasingly higher burden with subsequent production losses. The overall elasticity of emission gains to GDP losses is -1.1, that is a 40% reduction in CO_2 emissions through an outright quota is associated with a 36.8% loss of GDP. In this case, summing over the whole analyzed period, 2006 – 2020, the cumulative loss of GDP amounts to 1,145 billions TRY (2003 prices).

Table.1 The Incidence of CO_2 emission quotas and taxes on energy input

	Base Run	Under 90% Quota	Under 80% Quota	Under 60% Quota	Under 10% Tax on Energy	Under 20% Tax on Energy	Consumption Tax
Real GDP (2003 Prices, Billions TRY)							
2006	436.051	412.656	387.652	328.629	431.689	427.372	437.045
2008	490.023	461.451	430.940	359.300	483.061	476.332	490.966
2012	606.458	565.996	522.894	422.468	591.978	578.398	606.325
2020	952.704	876.495	795.750	608.880	908.290	868.182	943.503
Total CO2 Emissions (mtons)							
2006	276.953	249.258	221.562	166.172	243.775	217.507	259.729
2008	315.187	283.668	252.150	189.112	276.557	246.014	296.445
2012	401.368	361.231	321.094	240.821	349.440	308.568	379.029
2020	656.399	590.759	525.119	393.839	559.679	484.719	620.373
Total CO2 Emissions as a Ratio to GDP (million tones / billion TRY)							
2006	0.635	0.604	0.572	0.506	0.565	0.509	0.594
2008	0.643	0.615	0.585	0.526	0.573	0.516	0.604
2012	0.662	0.638	0.614	0.570	0.590	0.533	0.625
2020	0.689	0.674	0.660	0.647	0.616	0.558	0.658
CO2 Tax Revenues as a Ratio to GDP (%)							
2006		4.131	8.597	18.349	0.470	0.849	0.998
2008		3.815	7.941	16.928	0.471	0.852	0.985
2012		3.203	6.660	14.061	0.474	0.856	0.961
2020		2.057	4.218	8.169	0.478	0.863	0.911

The scenario is accompanied with a CO_2 tax to enforce the emission quotas. We find that total incidence of the CO_2 tax revenues as a ratio to the GDP is marginal for the 90% quota target. Yet, for enforcing a quota of 80%, the necessary tax burden is almost 10% upon implementation, and remains above 5% for the remaining of the projected time horizon. If a quota of 60% is envisaged the tax burden is 20% to the GDP and falls only to 12% in 2020. Thus, the model results suggest that for a return of 40% reduction in aggregate emissions in 2020, a CO_2 tax of 12% to the GDP is to be implemented. No wonder, this is an important interference to the economy and our results reveal that attempts to restrict the path of CO_2 emissions using fiscal measures alone will necessitate a very high tax incidence. In other words, the sensitivity of the production units to fiscal tax measure is very low, and that restricting CO_2 emissions in a growing economy is very costly and is very difficult to enforce.

The energy taxation at 10% leads to a reduction of total CO_2 emissions by 14.2% by 2020. If the tax rate is set at 20%, the abatement rate reaches to 25.3%. Figure 7 below depicts the path of aggregate CO_2 emissions under alternative taxation of energy input use. Thus, the energy taxation seems to have higher efficiency in combating CO_2 pollution at the aggregate level in contrast to taxing overall emissions. Since the major source of CO_2 pollutants originate from energy use, a taxation policy destined to economize on energy intensities seem to produce more efficient results to this end.

The overall tax burden of the current policy further illustrates this point. The model results suggest that the fiscal tax revenues from a 10% energy tax reach to only 0.48% of the GDP, and that from the imposition of 20% tax is 0.85% of the GDP. Thus in contrast to the significant burden of overall carbon taxes experienced in the previous scenarios, the energy taxation seem to carry lesser distortion to the domestic economy.

The loss in GDP from the imposition of a 20% energy tax rate is 7.4% in 2020 in comparison to the base run (business-as-usual). Thus to summarize, the model results suggest that the 20% energy taxation reduces overall CO_2 emissions by 25.3%, and is accompanied by a loss of aggregate GDP by 8.8% over the base run by 2020. In contrast the same figures were 14.2% CO_2 abatement rate in return to 10% energy tax and a loss of 3.9% in GDP level in 2020.

These results need to be contrasted with the very adverse effects of the current policy on the employment levels. The results indicate significant unemployment rates under the taxation regimes. The rate of open unemployment is observed to reach 15% under the 10% tax rate, and reaches 19% for the imposition of the 20% tax rate on energy use. In contrast, the base run path reveals a rate of unemployment of around 10% for most of the modeled time horizon. (Figure 4).

The rise of the unemployment rate under this scenario is due to the imposed distortions on cost minimization by introducing input taxes. To the extent that labor is complementary to energy use, the consequent rise in the costs of energy use leads fall in the demand for labor as well. With limited substitution possibilities in factor mix in the medium run, producers meet the increased energy costs by cutting demand not only for energy use, but also for labor employment, as well.

These results suggest that a proper mix of environmental taxation should be accompanied with reductions in labor taxes and/or increased subsidization to labor employment. Such a policy mix seems to be a superior policy in achieving both CO_2 abatement targets and maintaining employment rates across sectors. Furthermore, one observes a clear need for supplementing the market-based incentives along with direct abatement investments to reduce energy intensities and improve upon the existing pollution technologies.

4.2 Environmental Policy Instruments with Abatement Investments

An important issue in developing policies for the mitigation of greenhouse gas emissions is to determine a "feasible" set of policies to generate emission reductions and to make investments in energy-saving technologies. Estimating both the costs and effectiveness of these policies in emission-reduction is a very important, yet a challenging issue[9]

For the Turkish economy, a study has yet to be tackled to address the issues of estimating the costs of feasible policies to make investments in especially energy-saving, emission-reducing and cost-effective technological change that would be attractive to producers. In the absence of precise technological cost-benefit estimates of such investments, what we try to do in this section is to compare alternatives of burden-sharing between different groups in the economy, under a reference abatement-investment scenario.

Specifically, in the reference abatement-investment scenario, we follow the State Planning Organization estimates and implement energy-saving (CO_2 emission-reducing) abatement-investments of 1.5% of the GDP in 2006-2020. The SPO's estimate is that such investments will help reducing the energy-input related emission coefficients by 5%. We will adhere to this assumption in modeling of the abatement investment scenarios.

[9] The projection is developed by the National Technical University of Athens, Ecofys and AEA Technology and analyzed with the GENESIS database. It is based on EU-wide allocation of least-cost objective for different sectors. For instance, a recent study on the "Economic Evaluation of Sectoral Emission Reduction Objectives for Climate Change" conducted for EU countries project a marginal cost as low as 20-25 per tCO_2 eq. in 1999 €s for the EU countries. Such a marginal cost is estimated to compose €99 3.7 billion annually during the first budget period of the protocol (2008-2012), which is equivalent to about 0.06% of EU gross domestic product in 2010.

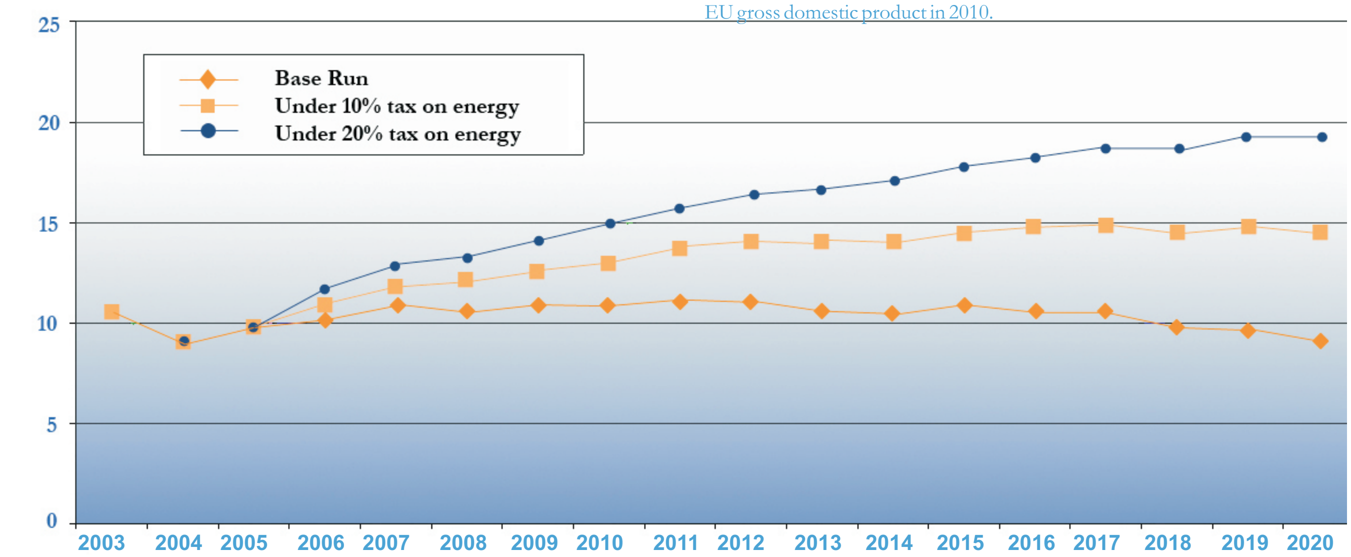

Figure.4 Unemployment rate under alternative energy tax scenarios

The question we are asking in this exercise is "what will happen, if total abatement investments (which is estimated to cost around 1.5% of GDP annually in 2006-2020), are undertaken by both the private and public production units to achieve a 5% reduction in emission coefficients of the primary-energy inputsþ" As the cost is undertaken totally by the investing sectors of the economy, it is clear that abatement investments will necessarily absorb a portion of funds away from physical capital accumulation. Thus, compared to base-run, the aggregate capital stock is expected to be reduced by the extent of such abatement investments.

It is the deceleration of the rate of physical capital investments that causes the slow down of the GDP growth. The real GDP under the scenario is found to be 5% lower than the corresponding value under base-run. Thus, the GDP growth rate is lower as well. This lower growth performance emerges as a result of the fall in the pace of capital accumulation, since a portion of investment now has been allocated for energy-saving, emissions-reducing technological change.

As investments lead to more efficient use of energy inputs and the emission coefficients on primary energy usage are effectively reduced, total CO_2 emissions are reduced. Such an application brings a total reduction of 549.3 million tones of CO_2 throughout 2003-2020 period. This value amounts to almost 7.5% of total emission level of the base-run. The annual reduction values indicate an average of 7.2% throughout the period, but as the reduction technology settles in, gains from emissions become more visible reaching as high as 15% of the baseline in 2020 (See Table 2).

Having observed the (potential) trade-off effects in allocation of funds towards abatement investments and away from capital investments (causing reduction in GDP), we next search for alternatives to finance the abatement investments. One alternative is that the government carries out the necessary investment expenditures (amounting to 1.5% of GDP, annually between 2006-2020), yet imposes additional taxes on the usage of polluting energy inputs (primary and secondary) in the production sectors to finance the investment projects.

The other alternative that we explore in this study is inspired by one "flexible" mechanism of the Kyoto protocol: the joint implementation (JI) mechanism that may be used by Annex I parties to fulfill their own Kyoto targets[11]. We assume the JI mechanism would offer incentives for the developed countries (Annex II) to be actively involved in projects; towards emission reductions.

So, in this scenario, we assume the abatement investments are financed by some form of foreign aid.

The intermediate energy usage tax policy results in a tax rate of 23% on the usage of refined petroleum (RP), petroleum and gas (PG) and coal (CO) in the production sectors. We present the effects of such policies on both the CO_2 emissions (total and sectoral distribution) and on the overall economic performance of the economy, in comparison to both the baseline and the first scenario under abatement investments affecting capital accumulation.

The financing of abatement investments by producers (both private and public) investing in capital accumulation, as well as relying on taxation of energy inputs, slow down the pace of economic activity, compared to both the baseline scenario and the scenario under foreign aid. On the other hand, under both scenarios of financing abatement investments from production units lower levels of CO_2 emissions are realized. This is due to slowing-down of the production activities in the overall economy. The scenario under foreign aid generates much favorable growth rates compared to the other two cases, nevertheless since the economic activity is higher, the total CO_2 emissions also rise. Yet, the abatement investments (which we assume effective in emission reduction) still accomplish a 3% reduction of total CO_2 emissions, compared to base-run.

The scenario under foreign aid has no direct effect on output/investment/input demand decisions of the production sectors, yet by offering funds to finance abatement investments, generates a proportional decrease in the sectoral and aggregate CO_2 emissions of the economy.

5. Conclusion

In this paper we utilized a computable general equilibrium model for Turkey to study the economic impacts of the intended policy scenarios of compliance with the Kyoto Protocol. Turkey is the only country which appears in the Annex-I list of the Rio Summit and yet an official target for CO_2 emission reductions has still not been established. Thus, as part of its accession negotiations with the EU, it will likely to face significant pressures to introduce its national plan on climate change along with specific emission targets and the associated abatement policies. Given this motivation, we report on the general equilibrium effects of various possible environmental abatement policies in Turkey

	Base Run	Under Abatement Inv. Affecting capital Acc.	Under Abatement Inv. Financed by Engy. Taxes	Under Abatement Inv. Financed by Foreign Aid
Real GDP (2003 Prices, Billions TRY)				
2006	436.051	429.929	418.168	436.051
2008	490.023	478.235	461.035	490.023
2012	606.458	579.218	544.509	606.458
2020	952.704	868.749	755.019	952.704
Total CO2 Emissions (mtons)				
2006	276.953	272.201	238.617	276.038
2008	315.187	304.734	266.294	312.063
2012	401.368	375.168	322.941	392.084
2020	656.399	571.459	460.917	624.091
Total CO2 Emissions as a Ratio to GDP (million tones / billion TRY)				
2006	0.635	0.633	0.571	0.633
2008	0.643	0.637	0.578	0.637
2012	0.662	0.648	0.593	0.647
2020	0.689	0.658	0.610	0.655

Table.2 The Incidence of abatement investments

Several policy conclusions emerge from our analysis:

1. Our modeling results suggest that the burden of possible imposition of direct carbon emission quotas would be quite high. This burden will necessitate a significant tax imposition on the producers to enforce the CO_2 quotas. According to our results, imposition of CO_2 quota at 60% level to the base run calls for a carbon tax of 20% – 15% over 2006 to 2020. The GDP loss incurred under this scenario is above 30% as of 2020.

2. Such a tax burden will likely lead to tax evasion practices, and will encourage the underground (informal) economy. Thus, it will likely lead to increased informalization of the production activities. The already high levels of producer tax incidences reduce the effectiveness of additional carbon taxation opportunities significantly.

3. In contrast to a direct "CO_2 quota-cum-carbon tax" policy, taxation of energy use in sectoral production seems to produce viable results. In returns to a 20% energy tax for producers, aggregate CO_2 emissions are reduced by 25.8% with a loss of GDP of 8.8% by the end of 2020. The energy taxation policy suffers strongly, however, from its very adverse employment effects. Unemployment rates rise significantly as a result of the introduced energy taxes. With limited substitution possibilities in input mix among labor and energy inputs, producers are bound to cut back labor employment as they are faced with increased energy costs.

4. The taxation policies suggest very clearly that possible interventions of new environmental taxes would have adverse outcomes either on employment or on sectoral output levels directly. A first-best policy would necessarily call for a simultaneous reduction on the existing tax burden on producers elsewhere together with introduction of environmental taxes. A reduction of employment taxes can be envisaged along with the imposition of energy tax use. Such a policy would be conducive in attaining CO_2 abatement targets together with employment incentives. Various studies show that using such tax revenues to finance reductions in the already existing (and mostly distortionary) taxes on employment, production, or sales can achieve superior outcomes with attaining environmental targets at lower cost –perhaps even at a positive net gain (see for example, Goulder et al, 1999; Perry et al, 1999; and Parry and Oates, 2000).

5. Overall, however, a first best environmental policy has to call for further incentives towards reducing energy intensities in production through more efficient production methods. By itself this is no easy task and certainly comes at significant investment cost. CGE modeling results suggest that leaving the burden of the abatement investments to production sectors alone create significantly adverse results in terms of overall economic performance. According to our results, abatement investments that amount to 1.5% of GDP annually call for 23% tax rate on energy (primary and secondary) input usage.

Photo: An industrial facility emitting CO_2

6. Further indirect taxes on the production sectors would likely trigger unfavorable dynamics in production and employment. Parallel to the reduction in output, one observes adverse outcomes on already high unemployment rates of the economy.

7. The advantageous environment likely to be produced by foreign aid on abatement investments displays high economic growth attained together with reductions in CO_2 emissions. An annual flow of foreign aid/credit of 1.5% as a ratio to the GDP designed to cover the costs of abatement investments for adoption of the "best available technologies" help reduce Turkish CO_2 emissions by 4.9% in 2020 and by a cumulative of 199.1 million tones over the whole analyzed period. By way of a caveat, it should be clear that designing such an international aid/credit system for the developing countries in their efforts towards abatement investments is by no means an easy task, and one should be aware that international coordination and cooperation, although crucial, could be difficult to achieve. The Protocol, as an international attempt itself, has been criticized for defining mechanisms that are too bureaucratic and cumbersome. Aldy et al (2003), for instance, point out to ambiguities in the existing institutional framework at the global scale, and identify more than a dozen competing approaches with regards to international carbon taxation and international technology standards.

8. A second caveat concerns the boundaries of our modeling paradigm. The CGE model is a technical laboratory device where the adjustment path as characterized by the simulation exercises reflects a "well-defined" and "smooth" general equilibrium system, based on consumer and producer optimization in the absence of any rigidities and/or structural bottlenecks. Thus, the adjustments of the model economy in response to various policy shocks should not be taken as a measure of the global stability properties of the real economy, but rather as a direct outcome of the laboratory characteristics of a set of macroeconomic simulations. For these reasons, our results should at best be regarded as crude approximations of the long-run equilibrium effects of environmental and investment policies on production, employment, current account capital accumulation and consumer welfare.

9. Finally, it should be noted that the model fails to identify the welfare benefits and possible productivity gains from reduced CO_2 emissions. Reductions in gaseous pollutants, for instance, are likely to lead to improved health conditions, enabling increases in labor productivity. Likewise, reductions in gaseous emissions would likely lead to further productivity gains in, say agriculture and food availability, due to improved climatic conditions. In the absence of detailed cost-benefit analysis of reducing CO_2 emissions on a micro level, we had to abstain from making ad hoc assumptions on such favorable external incidence of abatement investments.

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COST-BENEFIT ANALYSIS FOR IMPROVING ENERGY EFFICIENCY AND REDUCING GREENHOUSE GAS EMISSIONS IN THE TURKISH CEMENT INDUSTRY

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1. Introduction

Turkey became a party to United Nations Framework Convention on Climate Change on 24 May 2004, and started EU accession negotiations in the year 2005. In order to achive sustainable development and to meet the responsibilities imposed by international agreements and EC directives, Turkey must take measures in all economic sectors, especially in the energy intensive sectors of industry, to increase energy efficiency and to reduce the impact on environment. Detailed measures for two industrial sectors will be reported in TURKEY'S FIRST NATIONAL COMMUNICATION TO THE UNFCCC because of their high energy intensities and their strong impact on climate change, namely the cement industry and the iron and steel industry. The study presented in this report gives an in-depth analysis of the Turkish cement industry, identifies energy saving and carbondioxide emission reduction potentials, and develops an implementation schedule of the necessary measures based on cost-benefit analyses.

There are 41 integrated cement plants in Turkey which produce clinker and the final product cement. There are also 17 cement plants in Turkey which produce only cement from the clinker produced by other plants. The clinker production capacity of Turkey in the year 2004 was 39.0 million tons-clinker/year, whereas the realized production was 32.8 million tons-clinker/year. The cement grinding capacity in the same year was 66.0 million tons-cement/year which produced 38.8 million tons-cement during that year.

The aim of this report is to determine the possible measures, their investment costs and the schedule of their implementation to the Turkish cement industry between the years 2004-2020 for increasing energy efficiency, reducing production costs to internationally competitive levels, and reducing CO_2 emissions to levels imposed by international agreements.

2. The Aggregated Energy Efficiency and CO_2 Emission Model of the Turkish Cement Industry

An aggregated model of the Turkish cement industry was developed in this study in order to investigate the energy used for production, and to determine the CO_2 emissions resulting from use of energy (fuel and electricity) as well as from the chemical process of clinker production (Figure 1.1). The developed model was then used to investigate different scenarios concerning energy efficiency and CO_2 emissions, and the best implementation plan for the necessary measures to increase energy efficiency and to reduce CO_2 emissions was determined for the years between 2004 and 2020. The model developed in this study aggregates the 41 clinker plants in Turkey to a single plant with a production capacity equal to the total capacity of Turkey. The aggregated clinker plant displays the overall characteristics of energy usage and CO_2 emission of the individual plants. Similarly, the 58 existing cement grinding plants in Turkey are aggregated to a single cement grinding plant; all thermal power plants are aggregated to an equivalent thermal power plant; all hydraulic power plants are aggregated to an equivalent hydraulic power plant, and the Turkish interconnected electricity network is represented by an aggregated equivalent power line which connects the aggregated power stations to the aggregated clinker and cement production plants. The primary energy inputs to the model are aggregated fuel mixes used for production of clinker at the cement plants, and for production of electricity at the power plants. Raw material inputs to the model are aggregated raw material mix for clinker production, and aggregated additive mix for cement production.

CO_2 emissions of the model represent the total emissions of the Turkish cement industry in an aggregated form. CO_2 emissions result from calcination of the raw meal and burning of fuel in rotary kilns, and burning of fuel in thermal power plants which produce electricity for clinker production and cement grinding.

A questionaire form was prepared to determine the past and future status, and the future trends of the Turkish cement industry. Information concerning the system characteristics, production capacities, raw material and product specifications, energy consumptions, and measures to increase energy efficiencies were gathered. The participation of the companies to this activity has been encouraging; 24 companies, representing 60% of the integrated cement plants in Turkey, have filled out the questionaire form. The information obtained from these questionaire studies were used as the input data for the model. Additional data were obtained from the related literature, from archives of GEÇER Research Center of Gazi University, from the energy conservation studies carried of by the Turkish cement companies, plant visits, and contacts with General Directorate of Electrical Power Resources Survey and Development Administration (EİE), and Turkish Cement Manufacturers' Association (TÇMB).

Only two kilns with relatively small capacities utilize wet process in Turkey. In addition, the cement plants which had used fuel-oil before the 1973 energy crisis, have switched to coal since then. Therefore, the energy saving and CO_2 reduction measures considered in the model focuses specifically on plants which utilize dry clinker production system, and use coal as the fuel.

The model calculates the costs of saved energy (CSE's) for each measure. Then the CSE's (in \$/GJ) are compared to the primary energy purchase prices (PEP's in \$/GJ) as years progress. The implementation schedule of the energy saving measures in the years from 2004 to 2020 are determined by applying the criterion CSE<PEP, which results in The Energy Saving Supply Curve of the Turkish Cement Industry. The amounts of saved energy and CO_2 reduction by each measure, the required investment, year of implementation, limitations on implementation and logistics etc. are determined accurately and ahead of time in a systematic way by the use of the energy saving supply curve. The aggregated model developed in this study may also be used for energy efficiency and CO_2 emission analyses of single plants if appropriate inputs for single plants are used.

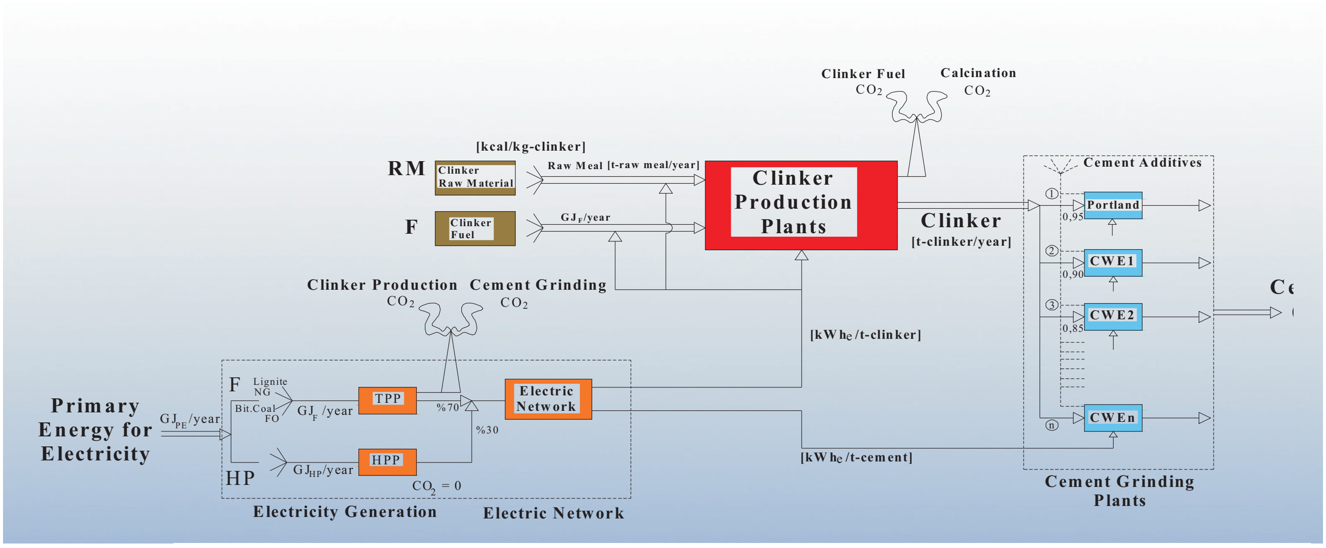

Figure 1.1 The aggregated energy efficiency and CO_2 emission model of the Turkish cement industry.

3. Increasing the Energy Efficiency of the Cement Industry

3.1 Implementation of Measures to Increase the Energy Efficiency of the Turkish Cement Industry

The possible measures for increasing the energy efficiency of the Turkish cement industry are listed in Table 1.1, along with their specific heat and electricity savings, specific investments, and their ratios of applicability to the total production capacity of Turkey.

The aggregated model was used to analyze each one of these measures, and the corresponding costs of saved energy (CSE's) were calculated for interest rate values of 12% and 30%. The measures were arranged in increasing order of their CSE values to obtain The Energy Saving Supply Curve of the Turkish Cement Industry (Table 1.2). Figure 1.2 and Figure 1.3 give the energy saving supply curves corresponding to 12% and 30% interest rates.

Table 1.1. Average specific heat and specific electricity savings and specific investment costs of measures.

Code Number of Measure	Measure	Specific Heat Saving (GJ/ton)	Specific Electricity Saving (kWh/ton)	Specific Investment Cost ($/ton-capacity)		Ratio of Applicability (%)
				1994	2004	
	MEASURES FOR RAW MEAL PREPARATION					
1	Using Efficient Transport Systems	0	2.25	5.36	6.61	31
2	Using Efficient Raw Meal Homogenization	0	1.79	6.61	8.16	40
3	Using Continuous Homogenization	0	0.5		3	53
4	Using Roller Press and Roller Mill	0	7.55	9.46	11.68	52
5	Using High Efficiency Classifiers	0	1.75	3.57	4.41	46
	MEASURES FOR CLINKER PRODUCTION					
6	Kiln Combustion System Improvements	0.052	0	0.98	1.21	30
7	Reduction of Kiln Shell Heat Losses	0.15	0	0.25	0.31	25
8a (%3 waste)	Use of Waste Fuels	0.10	0	1	1.23	50
8b (%6 waste)		0.21	0	1	1.23	50
8c (%12 waste)		0.42	0	1	1.23	50
9	Conversion to Modern Grate Coolers	0.3	-3	0.6	0.74	19
10	Heat Recovery for Power Generation (Only for long kilns in wet process)	0	20	3.25		
11	Conversion from Wet Process to Dry Process with Pre-heater, Pre-calciner Kiln	2.8	-10	75	92.59	1.36
12	Conversion to Multi-stage Cyclone Type Pre-heaters in Dry Process	0.9	0	20	24.69	0
13	Conversion to Low Pressure Drop, Multi-stage Cyclone, Suspension Pre-heaters in Dry Process.	0	4	3	3.70	100
14	Optimize Heat Recovery in Grate Coolers	0.08	0	0.2	0.25	40
15	Conversion of Long Dry Kiln to Multi-stage Pre-heater, Pre-calciner Kiln (Dry process)	1.3	0	28	34.57	0
16	Adding Pre-calciner to Pre-heater Kiln	0.4	0	4.79	5.92	24
	MEASURES FOR CEMENT GRINDING					
17	Using Efficient Transport Systems	0	2	3	3.70	47
18	Using Roller Press Pre-grinder before Ball Mills	0	8	2.5	3.09	41
19	Conversion from Ball Mill to Horomill	0	27	4	4.94	50
20	Using High Efficiency Classifiers	0	2.5	2.25	2.78	13
21	Improving Mill Internals	0	2	0.7	0.86	91
	GENERAL ENERGY SAVING MEASURES					
22	Preventive Maintenance (Insulation, reduction of pressurized air losses, preventive maintenance, etc.)	0.05	3	0.1	0.12	100
23	Process Control and Energy Management	0.2	4	1.5	1.85	17
24	Using High Efficiency Motors	0	1	0.2	0.25	100
25	Using Variable Speed Drives with Fans	0	4	0.10	0.12	46

Table 1.2. Energy saving measures arranged in order of increasing cost of saved energy (CSE).

Priority of Implementation	Code Number of Measure	CSE ($/GJ) (12% interest rate)	CSE ($/GJ) (30% interest rate)
1	22	0.198	0.479
2	7	0.255	0.618
3	9	0.337	0.815
4	14	0.367	0.886
5	25	0.409	0.989
6	23	0.972	2.351
7*	8a	1.602	3.873
8	16	1.836	4.439
9	19	2.494	6.030
10	10	2.736	6.614
11	6	2.875	6.949
12	15	3.301	7.980
13	24	3.367	8.140
14	12	3.406	8.234
15	11	4.243	10.258
16*	8b	0.815	1.970
17	18	5.261	12.719
18	21	5.893	14.245
19*	8c	0.407	0.985
20	13	12.627	30.526
21	20	15.165	36.660
22	4	21.105	51.020
23	17	25.254	61.051
24	5	34.359	83.063
25	1	40.086	96.906
26	2	62.293	150.593
27	3	81.823	197.805

** Order is determined by enforcing the implementation year.*

As observed from Table 1.2, the measure with the code number 22 has the minimum value of CSE, and is the most advantageous measure. On the other hand, the measure with the code number 3 has the highest value of CSE, and must be implemented with the least priority. The measures 8b and 8c seem to violate the order. This is caused by constraints placed on the ratio of waste fuel used, which is assumed to be 0%, 3%, 6% and 12% in the years 2004, 2010, 2015 and 2020 respectively, and applied to 50% of the total production capacity.

The results show that using a lower value for the interest rate shifts imlementation of the measures to earlier years, while using a higher value of interest rate shifts them to the later years. The rate of increase of CSE's is 3 to 5 times less than the rate of increase of PEP's; therefore, applying measures with higher CSE values becomes feasible as years progress.

The values of PEP ($/GJ) for the years 2010, 2015, 2020 are shown by horizontal lines in Figures 3.1 and 3.2. The criterion for implementation of an energy saving measure is expressed as “Cost of Saved Energy CSE ($/GJ) < Primary Energy Price PEP ($/GJ)”. In other words, those measures with CSE values which are below the horizontal line corresponding to the PEP value of a specific year can be implemented feasibly before that specified year.

Figures 3.1 and 3.2 show code numbers of the measures which may be implemented on or before the milestone years 2005, 2010, 2015 and 2020. The steady decrease of the specific primary energy consumption for cement production (GJ/t-cement) between 2004 and 2020 is also observed in Figures 1.2 and 1.3. The specific primary energy consumption is 4.00 GJ/ton-cement in the year 2004. It drops to 2.84 GJ/ton-cement and 2.87 GJ/ton-cement for interest rates of 12% and 30% respectively in the year 2020. Therefore, reduction in the specific primary energy consumption from 2004 to 2020 is 29% if interest rate is 12%, and 28% if interest rate is 30%.

3.2. Scenario Studies

Three scenario studies were carried out by using the aggregated model. These scenarios allow one to make comparisons between the following cement production alternatives: i) Using technology of 1990, ii) Using technology of 2004, iii) Implementing measures after the year 2004 for saving energy.

3.2.1. Scenario 1: Using the Technology of 1990 for Production

This scenario assumes that the technology which was available in 1994 is used for producing cement between the years 2004 and 2020. Therefore, specific primary energy consumpion is assumed to be 4.35 GJ/t-cement for the existing plants. The scenario assumes that the capacities of the existing plants are used so long as there is available capacity. When the existing capacity is completely used up, additional capacity is created by adding pre-calciners to the existing plants, in which case the energy savings due to pre-calciners are also taken into account. The expanded capacity due to newly added pre-calciners becomes insufficient in the year 2015, then new plants with the latest technology are assumed to be constructed to create additional production capacity. The technologies used in the new plants depend on the prevailing economical conditions; hence, they may have different measures applied to them depending on whether 12% or 30% interest rate is assumed.

The total primary energy consumption of the Turkish cement industry for this scenario is given in Table 1.3. The total energy used in 2020 is 235.7 PJ/year and 236.0 PJ/year for the interest rate values of 12% and 30% respectively, which are 268% higher than the corresponding value for the year 1990.

Table 1.3 The total primary energy consumptions if technology of 1990 is used for production. (Note: 1 PJ = 10^{15} Joule)

Years	1990	2004	2010	2015	2020
Total Primary Energy Consumption (PJ/year) (12% interest rate)	88.02	142.47	189.91	210.81	235.66
Total Primary Energy Consumption (PJ/year) (30% interest rate)	88.02	142.47	189.91	210.84	235.98

3.2.2. Scenario 2: Using the Technology of 2004 for Production

This scenario assumes that the technology of 2004 is used after the year 2004. Therefore, specific primary energy consumpion is assumed to be 4.35 GJ/t-cement for the years between 1990 and 2004, and 4.0 GJ/t-cement for all years after 2004, except for the newly constructed plants or the plants with newly installed precalciners. The assumptions concerning expansion of capacity are the same as in Scenario 1.

The total primary energy consumptions for Scenario 2 are given in Table 3.4. The total energy used in 2020 is 218.7 PJ/year and 219.0 PJ/year for the interest rate values of 12% and 30% respectively, which is 248% higher than the value for the year 1990.

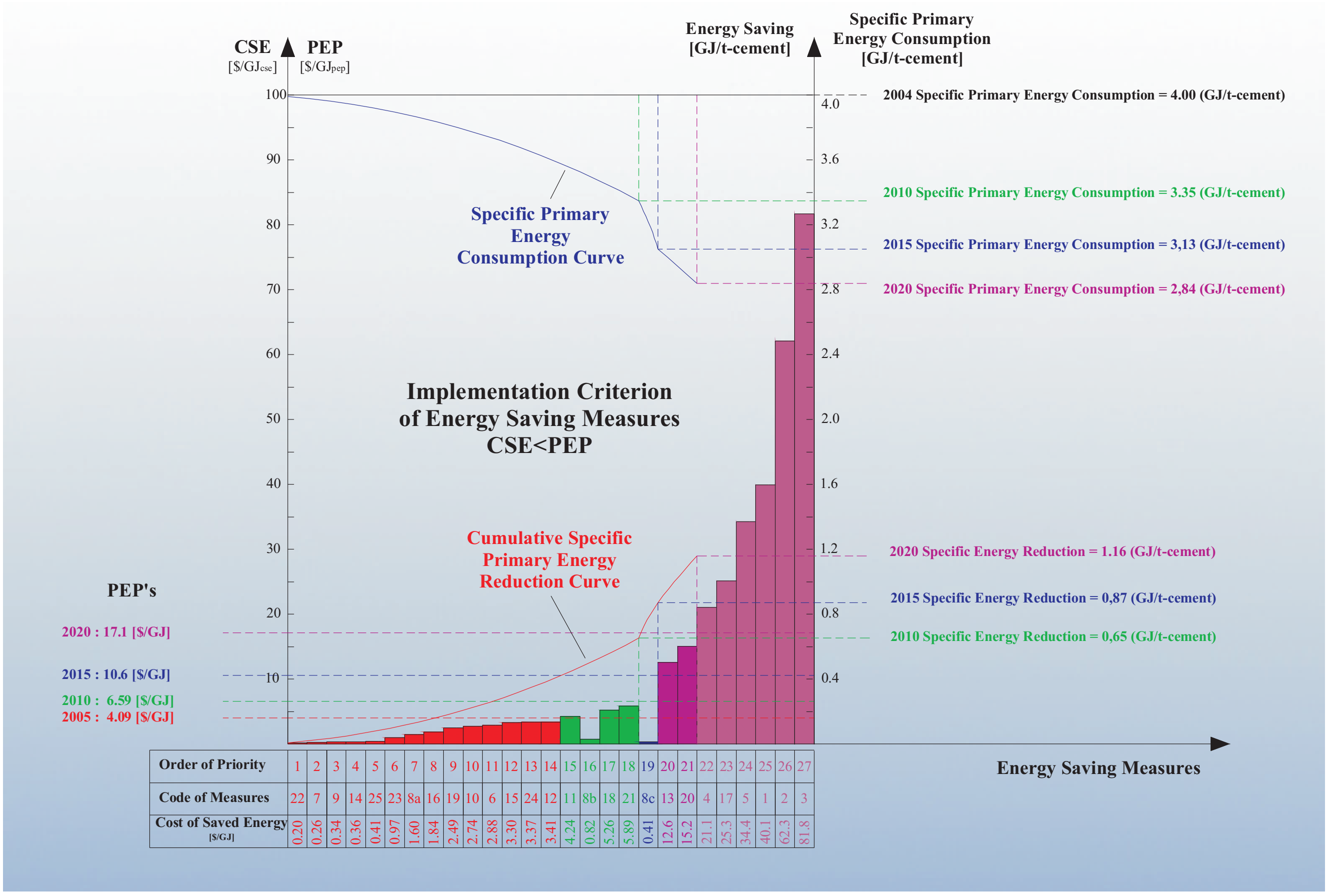

Figure 1.2 The energy saving supply curve of the Turkish cement industry and the years of implementing energy saving measures (12% interest rate, waste fuel used).

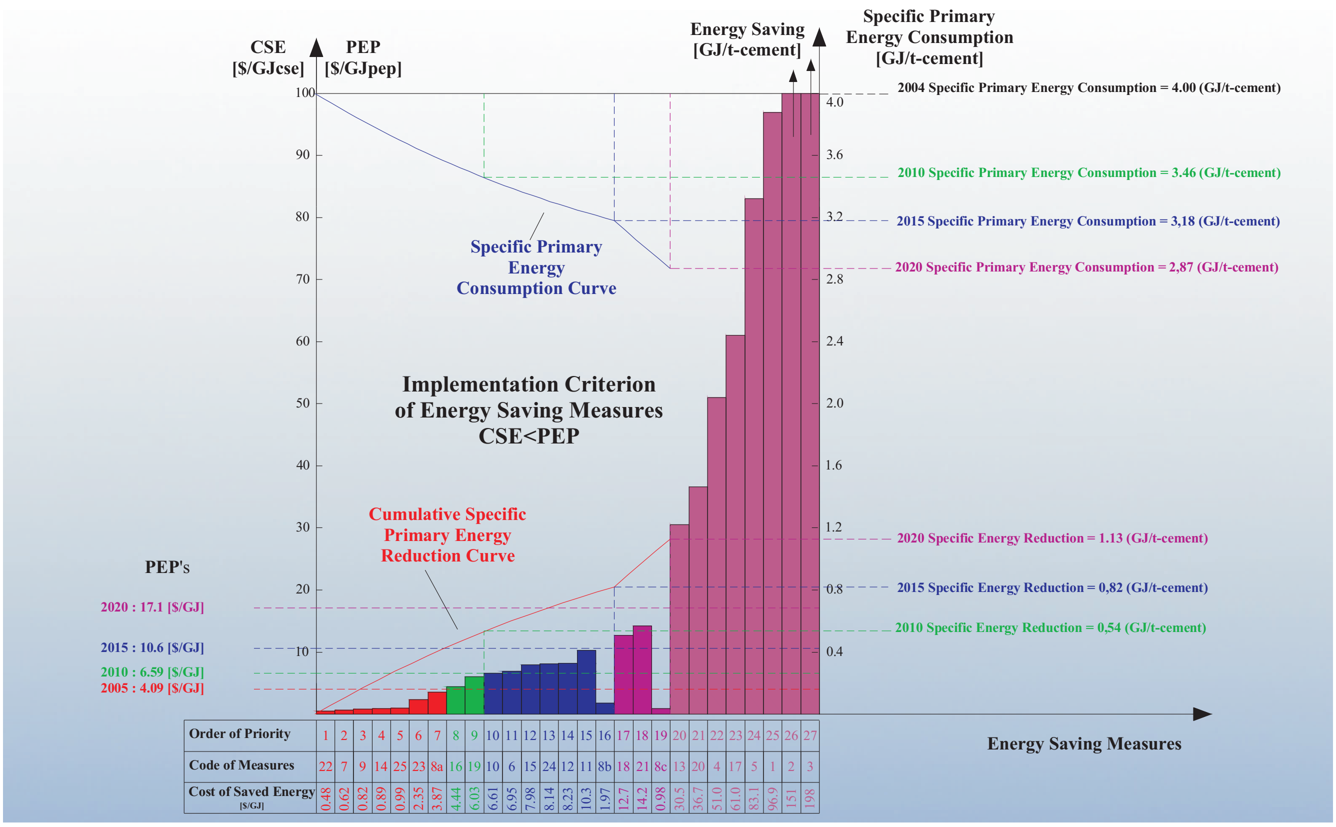

Figure 1.3 The energy saving supply curve of the Turkish cement industry and the years of implementing energy saving measures (30% interest rate, waste fuel used).

Table 1.4 The total primary energy consumptions if technology of 2004 is used for production.

Years	1990	2004	2010	2015	2020
Total Primary Energy Consumption (PJ/year) (12% interest rate)	88.02	131.06	174.55	193.83	218.68
Total Primary Energy Consumption (PJ/year) (30% interest rate)	88.02	131.06	174.55	193.86	219.00

3.2.3. Senaryo 3: Implementing Energy Saving Measures After the Year 2004

Scenario 3 assumes that energy saving measures are implemented after the year 2004 according to the energy saving supply curves given in Figures 1.2 and 1.3, and the priority order given in Table 1.2. The total primary energy consumption of the Turkish cement industry for this scenario, as well as for the prevous two scenarios is given in Table 1.5.

Table 1.5 The total primary energy consumptions (12% interest rate).

Years	1990	2004	2010	2015	2020
Scenario 1: Primary Energy Consumption If Technology of 1990 is Used (PJ/year)	88.02	142.47	189.91	210.81	235.66
Scenario 2: Primary Energy Consumption If Technology of 2004 is Used (PJ/year)	88.02	131.06	174.55	193.83	218.68
Scenario 3: Primary Energy Consumption If Energy Saving Measures are Implemented after 2004 (PJ/year)	88.02	131.06	148.02	155.15	165.96

4. Determination of the CO_2 Emissions from the Cement Industry and the Emission Scenarios

4.1. Calculation of CO_2 Emissions

CO_2 emissions of the Turkish cement industry were calculated also by using The Aggregated Energy Efficiency and CO_2 Emission Model given in Section 2. Figure 1.1 shows the CO_2 emission sources of the cement industry. The stacks of rotary kilns of clinker production plants and the stacks of power plants which supply electricity for cement production emit CO_2. The aggregated model calculates the components of CO_2 emission as explained below, and determines the total emissions by summing them.

4.1.1. CO_2 Emissions Resulting from Calcination of the Raw Meal

The raw materials used for clinker production in Turkey have negligible amounts of CaO and MgO. On the other hand, the clinker produced has an average content of 60-67% CaO and 0.1-4% MgO which result from the $CaCO_3$ and $MgCO_3$ present in the raw materials. Based on these data, the specific CO_2 emission resulting from calcination of the raw meal was determined as 520 kg-CO_2/ton-clinker.

4.1.2. Co_2 Emissions Resulting from the Fuel Burned for Production of Clinker

The fuel mix and CO_2 emission factors of fuels were assumed to be the same for all years in the model.

However, the average combined emission factors expressed in terms of kg-CO_2-mixedfuel/ton-clinker were calculated for each year by considering the emission factors, the fuel mix, the heating values of fuels and the specific heat needed for clinker production. For example, the emission factor calculated like this was 335.7 kg-CO_2-mixedfuel/ton-clinker for the year 2004.

4.1.3. CO_2 Emissions from Power Plant Stacks Due to Production of Electricity Used in Clinker Production

The model assumes that the ratio of thermal to hydraulic electricity production, the average efficiencies of thermal power plants and the efficiency of transportation and distribution of electricity stay constant throughout the years. The real values of fuel usage ratios are used for the years 1990 and 2004. The fuel usage ratios for the years after 2004 are assumed to be the same as for 2004.

Average combined emission factors expressed in terms of kg-CO_2-thpfuel/ton-clinker were calculated for each year by considering the emission factors, the fuel mix, the heating values of fuels and the specific electricity needed for clinker production. For example, the emission factor calculated like this was 49.9 kg-CO_2-thpfuel/ton-clinker for the year 2004.

4.1.4. CO_2 Emissions from Power Plant Stacks Due to Production of Electricity Used in Cement Grinding

The average combined emission factors expressed in terms of kg-CO_2-thpfuel/ton-cement were calculated for each year by considering the emission factors, the fuel mix, the heating values of fuels and the specific electricity needed for grinding of cement. For example, the emission factor calculated like this was 30.95 kg-CO_2-thpfuel/ton-cement for the year 2004.

4.2. Scenario Studies

The Agregated Energy Efficiency and CO_2 Emission Model may be used for studying different CO_2 emission scenorios by changing the underlying assumptions and the input data. The three scenario studies which were presented in Section 3 were used also in calculation of the CO_2 emissions.

4.2.1. Scenario 1: Using the Technology of 1990 for Production

The results obtained from Scenario1 are presented below in Tables 1.6-1.8 for interest rate values of 12% and 30%.

Table 1.6 The CO_2 emissions if the technology of 1990 is used for production (12% interest rate).

Years	1990	2004	2010	2015	2020
CO_2 Emission from Calcination (million ton-CO_2/year)	10.54	17.06	22.99	25.88	30.43
CO_2 Emission from Fuel Used for Clinker Production (million ton-CO_2/year)	7.61	12.31	16.59	18.59	21.07
CO_2 Emission from Production of Electricity Used in Clinker Production (million ton-CO_2/year)	1.40	2.26	3.05	3.41	3.79
CO_2 Emission from Production of Electricity Used in Cement Grinding (million ton-CO_2/year)	1.05	1.66	2.27	2.66	3.01
Total CO_2 Emission (million ton-CO_2/year)	20.59	33.29	44.89	50.53	58.29

Table 1.7 The CO_2 emissions if the technology of 1990 is used for production (30% interest rate).

Years	1990	2004	2010	2015	2020
CO_2 Emission from Calcination (million ton-CO_2/year)	10.54	17.06	22.99	25.88	30.43
CO_2 Emission from Fuel Used for Clinker Production (million ton-CO_2/year)	7.61	12.31	16.59	18.59	21.07
CO_2 Emission from Production of Electricity Used in Clinker Production (million ton-CO_2/year)	1.40	2.26	3.05	3.41	3.81
CO_2 Emission from Production of Electricity Used in Cement Grinding (million ton-CO_2/year)	1.05	1.66	2.27	2.66	3.01
Total CO_2 Emission (million ton-CO_2/year)	20.59	33.29	44.89	50.54	58.32

Table 1.8 The total CO_2 emissions if the technology of 1990 is used for production.

Years	1990	2004	2010	2015	2020
Total CO_2 Emission (12% interest rate) (million ton-CO_2/year)	20.59	33.29	44.89	50.53	58.29
Total CO_2 Emission (30% interest rate) (million ton-CO_2/year)	20.59	33.29	44.89	50.54	58.32

4.2.2. Scenario 2: Using the Technology of 2004 for Production

The results obtained from Scenario 2 are presented below in Tables 1.9 - 1.11 for interest rate values of 12% and 30%.

Table 1.9 The CO_2 emissions if the technology of 2004 is used for production (12% interest rate).

Years	1990	2004	2010	2015	2020
CO_2 Emission from Calcination (million ton-CO_2/year)	10.54	17.06	22.99	25.88	30.43
CO_2 Emission from Fuel Used for Clinker Production (million ton-CO_2/year)	7.61	11.00	14.83	16.64	19.12
CO_2 Emission from Production of Electricity Used in Clinker Production (million ton-CO_2/year)	1.40	1.63	2.20	2.47	2.85
CO_2 Emission from Production of Electricity Used in Cement Grinding (million ton-CO_2/year)	1.05	1.20	1.64	1.92	2.23
Total CO_2 Emission (million ton-CO_2/year)	20.59	30.90	41.66	46.92	54.63

Table 1.11 The total CO_2 emissions if the technology of 2004 is used for production.

Years	1990	2004	2010	2015	2020
Total CO_2 Emission (12% interest rate) (million ton-CO_2/year)	20.59	30.90	41.66	46.92	54.63
Total CO_2 Emission (30% interest rate) (million ton-CO_2/year)	20.59	30.90	41.66	46.92	54.66

Table 1.10 The CO_2 emissions if the technology of 2004 is used for production (30% interest rate).

Years	1990	2004	2010	2015	2020
CO_2 Emission from Calcination (million ton-CO_2/year)	10.54	17.06	22.99	25.88	30.43
CO_2 Emission from Fuel Used for Clinker Production (million ton-CO_2/year)	7.61	11.00	14.83	16.64	19.12
CO_2 Emission from Production of Electricity Used in Clinker Production (million ton-CO_2/year)	1.40	1.63	2.20	2.48	2.88
CO_2 Emission from Production of Electricity Used in Cement Grinding (million ton-CO_2/year)	1.05	1.20	1.64	1.92	2.23
Total CO_2 Emission (million ton-CO_2/year)	20.59	30.90	41.66	46.92	54.66

4.2.3. Senaryo 3: Implementing Energy Saving Measures After the Year 2004

Scenario 3 assumes that energy saving measures are implemented after the year 2004 according to the energy saving supply curves given in Figures 1.2 and 1.3, and the order of priority given in Table 1.2. The CO_2 emissions obtained from Scenario 3 are presented in Tables 1.12 – 1.14. Comparisons of CO_2 emissions obtained from the three scenarios studied are presented in Tables 4.15 – 4.16.

Table 1.12 The CO_2 emissions if energy saving measures are implemented after 2004 (12% interest rate).

Years	1990	2004	2010	2015	2020
CO_2 Emission from Calcination (million ton-CO_2/year)	10.54	17.06	22.99	25.88	30.43
CO_2 Emission from Fuel Used for Clinker Production (million ton-CO_2/year)	7.61	11.00	13.09	14.51	16.54
CO_2 Emission from Production of Electricity Used in Clinker Production (million ton-CO_2/year)	1.40	1.63	2.02	2.28	2.52
CO_2 Emission from Production of Electricity Used in Cement Grinding (million ton-CO_2/year)	1.05	1.20	0.99	1.16	1.40
Total CO_2 Emission (million ton-CO_2/year)	20.59	30.90	39.09	43.82	50.90

Table 1.13 The CO_2 emissions if energy saving measures are implemented after 2004 (30% interest rate).

Years	1990	2004	2010	2015	2020
CO_2 Emission from Calcination (million ton-CO_2/year)	10.54	17.06	22.99	25.88	30.43
CO_2 Emission from Fuel Used for Clinker Production (million ton-CO_2/year)	7.61	11.00	13.32	14.51	16.54
CO_2 Emission from Production of Electricity Used in Clinker Production (million ton-CO_2/year)	1.40	1.63	2.06	2.28	2.68
CO_2 Emission from Production of Electricity Used in Cement Grinding (million ton-CO_2/year)	1.05	1.20	1.16	1.37	1.41
Total CO_2 Emission (million ton-CO_2/year)	20.59	30.90	39.53	44.03	51.07

Table 1.14 The total CO_2 emissions if energy saving measures are implemented after 2004.

Years	1990	2004	2010	2015	2020
Total CO_2 Emission (12% interest rate) (million ton-CO_2/year)	20.59	30.90	39.09	43.82	50.90
Total CO_2 Emission (30% interest rate) (million ton-CO_2/year)	20.59	30.90	39.53	44.03	51.07

Table 1.15 Comparison of CO_2 emissions for the investigated scenarios (12% interest rate).

Years	1990	2004	2010	2015	2020
Scenario 1: CO_2 Emissions If Technology of 1990 is Used (million ton-CO_2/year)	20.59	33.29	44.89	50.53	58.29
Scenario 2: CO_2 Emissions If Technology of 2004 is Used (million ton-CO_2/year)	20.59	30.90	41.66	46.92	54.63
Scenario 3: CO_2 Emissions If Energy Saving Measures are Implemented after 2004 (million ton-CO_2/year)	20.59	30.90	39.09	43.82	50.90

Table 1.16 Comparison of CO_2 emissions for the investigated scenarios (30% interest rate).

Years	1990	2004	2010	2015	2020
Scenario 1: CO_2 Emissions If Technology of 1990 is Used (million ton-CO_2/year)	20.59	33.29	44.89	50.54	58.32
Scenario 2: CO_2 Emissions If Technology of 2004 is Used (million ton-CO_2/year)	20.59	30.90	41.66	46.92	54.66
Scenario 3: CO_2 Emissions If Energy Saving Measures are Implemented after 2004 (million ton-CO_2/year)	20.59	30.90	39.53	44.03	51.07

5. Conclusions

The study presented in this report gives an in-depth analysis of the Turkish cement industry, identifies the energy saving and carbondioxide emission reduction potentials, and developes an implementation schedule of the necessary measures, based on cost-benefit analyses. An aggregated model of the Turkish cement industry was developed in this study in order to investigate the energy used for production, and to determine the CO_2 emissions resulting from use of energy (fuel and electricity) as well as from the chemical process of clinker production (Figure 1.1).

The model developed in this study aggregates the clinker plants, cement grinding plants, the power plants which produce electricity for cement production, and the interconnected electricity network suppling electricity to the cement plants to single plants respectively. The aggregated components of the model represent the total production capacities, and the overall energy usage and the CO_2 emission characteristics of the individual plants in Turkey.

Possible measures to save energy in the cement production were determined, and the aggregated model was used to calculate the costs of saved energy (CSE's) for each measure (Section 3). Then the CSE's (in $/GJ) were compared to the primary energy purchase prices (PEP's in $/GJ) as years progress. The implementation schedule of the energy saving measures from the years 2004 to 2020 were determined by applying the criterion CSE<PEP, which resulted in The Energy Saving Supply Curve of the Turkish Cement Industry. The amounts of saved energy and the CO_2 reduction by each measure, the required investment and the year of implementation were determined by the use of the energy saving supply curve.

The following three scenarios were studied by using the energy saving supply curves for the interest rate values of 12% and 30%:

Scenario 1: Using the Technology of 1990 for Production

Scenario 2: Using the Technology of 2004 for Production

Scenario 3: Implementing Energy Saving Measures After the Year 2004

Figure 1.4 shows the total primary energy consumptions of the Turkish Cement Industry for the investigated scenarios. The corresponding values of the energy costs, specific heat consumptions and specific electricity consumptions are given in Figure 1.5, Figure 1.6 and Figure 1.7 respectively.

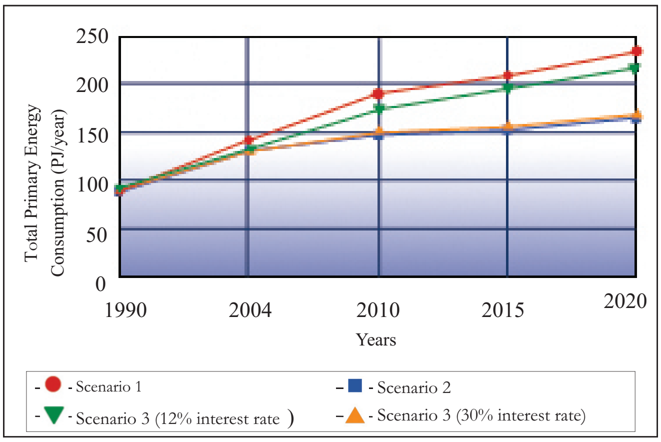

Figure 1.4 The total primary energy consumptions of the Turkish cement industry for the investigated scenarios.

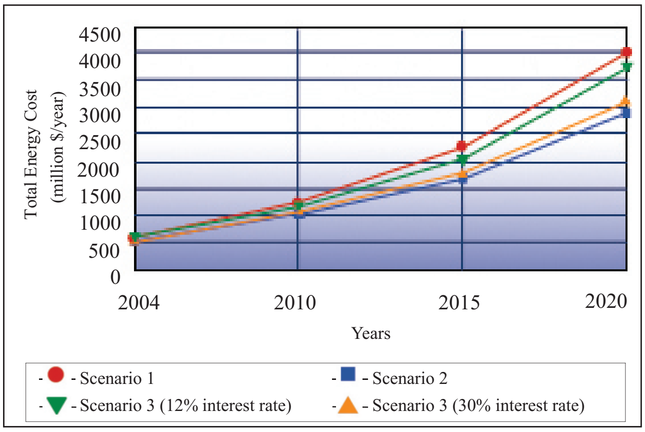

Figure 1.5 The total energy costs of the Turkish cement industry for the investigated scenarios.

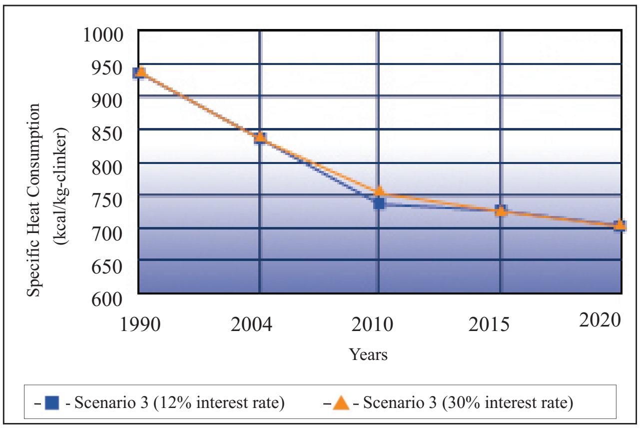

Figure 1.6 The specific heat consumptions of the Turkish cement industry if measures are taken after the year 2004.

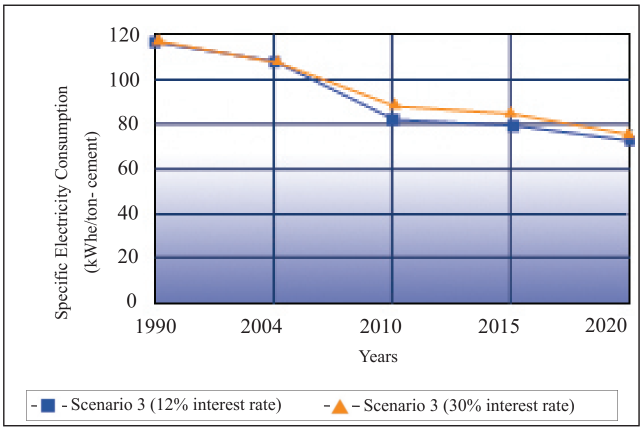

Figure 1.7 The specific electricity consumptions for cement with additive of the Turkish cement industry if measures are taken after the year 2004.

As demonstrated by these figures, the Turkish cement industry has taken some measures, and done rehabilitation work to save energy between the years 1990 and 2004 by making considerable investments. As a result of these activities reductions in energy consumption and energy cost have been achieved in the year 2004 as compared to 1990, as shown in Table 1.17 given.

Table 1.17 The savings resulting from measures taken between the years 1990 and 2004.

Quantity	Reduction in 2004 as Compared to 1990	
	Absolute Reduction	Percent Reduction
Total Primary Energy Consumption	11.41 PJ/year	8%
Total Cost of Energy	46.71 $/year	8%
Specific Heat Consumption	99.3 kcal/kg-clinker	10.6%
Specific Electricity Consumption	10.81 kWh_e/ton-cement	9.1%

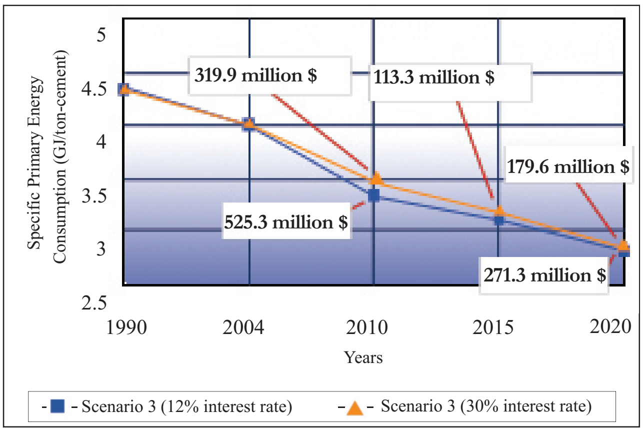

Figure 1.8 Change of the specific primary energy consumptions of cement with additives by years and the investments.

Figure 1.8 shows the specific primary energy consumptions and the corresponding investment costs if energy saving measures are implemented starting in the year 2004 (Scenario 3) for interest rates of 12% and 30%.

Lowering the interest rate to 12% increases the number of measures taken between the years 2004 and 2010. In this case no measures are taken between the years 2010 and 2015. Implementation of waste fuel use is enforced to be 3%, 6% and 12% (applied to 50% of the total capacity) in the years 2010, 2015 and 2020 respectively. If the interest rate is 30%, the number of measures taken between the years 2004 and 2010 decreases. These measures are shifted to the years between 2010 and 2015.

Figure 1.8 shows that specific primary energy consumption reduces from 4.00 GJ/ton-cement in the year 2004 to 2.84 GJ/ton-cement in 2020 if the interest rate is 12%. The required investment to realize this reduction is 525.3 million $ in the year 2010, and 271.3 million $ in the year 2020. These investment costs are in terms of the dollars of the specified years.

Specific primary energy consumption reduces from 4.00 GJ/ton-cement in the year 2004 to 2.87 GJ/ton-cement in 2020 if the interest rate is 30%. The required investment to realize this reduction is 319.9 million $ in the year 2010, 113.3 million $ in the year 2015, and 179.6 million $ in the year 2020.

If the interest rate is 12 % and waste fuel is used, the specific heat consumption for clinker production reduces from 836.6 kcal/kg-clinker in the year 2004 to 705.07 kcal/kg-clinker in the year 2020, which represents a decrease of 16% (Figure 1.6).

Correspondingly, the specific electricity consumption for cement with additives reduces by 32.2 % from 107.86 kWhe/ton-cement to 73.12 kWhe/ton-cement (Figure 1.7). If no waste fuel is used the specific heat consumption for clinker production becomes 750.07 kcal/kg-clinker in the year 2020. If the interest rate is 30% and waste fuel is used, the specific heat consumption for clinker production reduces by 16% from 836.6 kcal/kg-clinker in the year 2004 to 705.07 kcal/kg-clinker in the year 2020, which is the same as for 12% interest rate. In this case, the specific electricity consumption for cement with additives reduces to 76.25 kWhe/ton-cement, representing a reduction of 29.3% compared to 2004 (Figure 1.7).

The results show that the reductions from 2004 to 2020 in specific primary energy consumption, specific heat consumption and specific electricity consumption are quite insensitive to the value of interest rate. Interests rate effects the implementation times of the measures rather than the outcome in the year 2020.

CO_2 emission calculations were carried out also for the same scenarios (Section 4). The total CO_2 emissions of the Turkish cement industry are shown in Figure 1.9. The total CO_2 emission was 20.59 million ton-CO_2/year in 1990. If production were carried out by using the technology of 1990, the total CO_2 emission would have been 33.29 million ton-CO_2/year in the year 2004. The results in Figure 5.6 demonstrate that the CO2 emissions of the Turkish cement industry has been reduced by 2.39 million ton-CO_2/year or by %7 from the year 1990 to 2004 (Scenario 1 value - Scenario 2 value in the year 2004) as a result of voluntary measures taken during this period. If production is carried out by using technologies of 1990, the total CO_2 emissions in 2020 will be 58.29 million ton-CO_2/year, whereas if the technology of 2004 is used it will be 54.63 million ton-CO_2/year. However, if energy saving measures are implemented after 2004, the total CO_2 emissions will be 50.90 million ton-CO_2/year for 12% interest rate, and 51.07 million ton-CO_2/year for 30% interest rate. The reduction in the total CO_2 emission in 2020 as a result of taking proper measures is 7.4 million ton-CO_2/year, or 12.7% compared to Scenario 1 emissions for the interest rate of 12%, and 7.2 million ton-CO_2/year, or 12.4% for the interest rate of 30%.

Figures 1.10 shows the changing of specific CO_2 emissions of cement with additives by years for the cases with 12% and 30% interest rates respectively. The specific CO_2 emission, which is 770.66 kg-CO_2/ton–cement in the year 2004, reduces to 610.94 kg-CO_2/ton–cement or by 21% if the interest rate is 12%.

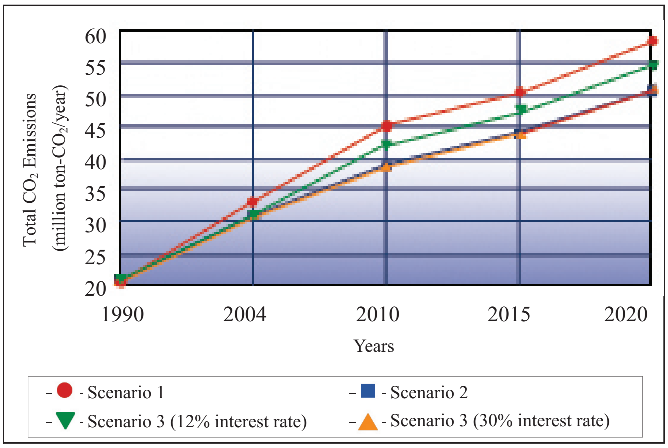

Figure 1.9 The total CO_2 emissions of the Turkish cement industry for the investigated scenarios.

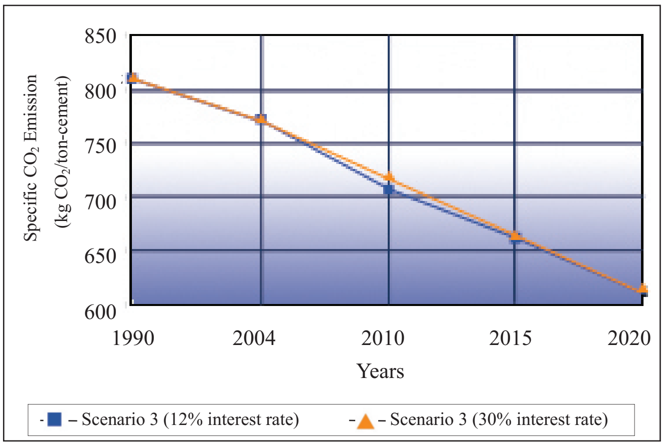

Figure 1.10 The specific CO_2 emissions of cement with additives

For the case with 30% interest rate, the specific CO_2 emission reduces to 613.02 kg-CO_2/ton–cement or by 20% in the year 2020. The specific CO_2 emission in the year 1990 was 809.42 kg-CO_2/ton–cement. Hence, the specific CO_2 emission reduction from 1990 to 2020 is 24.5% for the interest rate of 12%, and 24.3% for the interest rate of 30%.

NOTES

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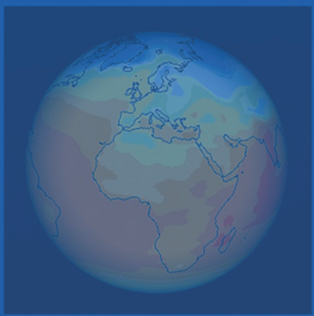

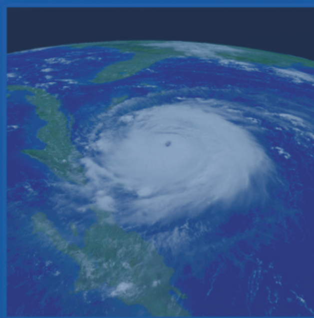

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