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Carbon dioxide emission from the Turkish electricity sector and its mitigation options

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ABSTRACT

In this study, electricity generation associated CO₂ emissions and fuel-specific CO₂ emission factors are calculated based on the IPCC methodology using the data of fossil-fueled power plants that ran between 2001 and 2008 in Turkey. The estimated CO₂ emissions from fossil-fueled power plants between 2009 and 2019 are also calculated using the fuel-specific CO₂ emission factors and data on the projected generation capacity of the power plants that are planned to be built during this period. Given that the total electricity supply (planned+existing) will not be sufficient to provide the estimated demand between 2011 and 2019, four scenarios based on using different fuel mixtures are developed to overcome this deficiency. The results from these scenarios show that a significant decrease in the amount of CO₂ emissions from electricity generation can be achieved if the share of the fossil-fueled power plants is lowered. The *Renewable Energy Scenario* is found to result in the lowest CO₂ emissions between 2009 and 2019. The associated CO₂ emissions calculated based on this scenario are approximately 192 million tons lower than that of the *Business As Usual Scenario* for the estimation period.

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1. Introduction

Industrialization, high population growth, and urbanization cause the depletion of natural resources and numerous environmental problems. Fossil fuel consumption, as a depletion of natural resources, results in the increase of greenhouse gas (GHG) emissions in the atmosphere. The concentration of atmospheric CO₂, which is

Abbreviations: Avg, average; BAU, business as usual; EFT, Environment Foundation of Turkey; EGIC, Electricity Generation Incorporated Company [EUAS in Turkish]; EMRA, Energy Market Regulatory Authority [EPDK in Turkish]; EPSA, Electrical Power Survey and Administration [EIE in Turkish]; Geo, geothermal; GHG, greenhouse gas; GNAT, The Grant National Assembly of Turkey [TBMM in Turkish]; GWh, gigawatt hour; IEA, International Energy Agency; IPCC, Intergovernmental Panel on Climate Change; kWh, kilowatt hour; LHV, low heating value; LPG, liquefied petroleum gas; MENR, ministry of Energy and Natural Resources [ETKB in Turkish]; MoEF, Ministry of Environment and Forestry [ÇOB in Turkish]; MW, megawatt; MWG, municipal waste gas; MWh, megawatt hour; NG, natural gas; NIR, National Inventory Report; NLDC, National Load Distribution Center; OECD, Organization for Economic Cooperation and Development; ppm, parts per million; SEF, specific emission factor; SHW, state hydraulic works [DSI in Turkish]; SPO, State Planning Organization [DPT in Turkish]; TETC, Turkish Electricity Transmission Corporation [TEIAS in Turkish]; TURKSTAT, Turkish Statistical Institute [TUİK in Turkish]; UNFCCC, United Nations Framework Conventions on Climate Change

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the major GHG, has increased from a pre-industrial value of approximately 280–379 ppm as of 2005 (IPCC, 2007). Changes in sea level, snow cover, ice sheets, and rainfall are results of global climate change, and all these disasters affect ecosystems in many parts of the world (UNFCCC, 2006).

Because the climate change problem threatens all living beings, the solution to this problem needs to be dealt with globally. Thus, the United Nations took a step to handle this global problem at the United Nations Framework Convention on Climate Change (UNFCCC). The ultimate objective of the UNFCCC is to stabilize the GHG concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. To accomplish this task, significant GHG emission reduction is required (IEA, 2009).

As a party to UNFCCC and Kyoto Protocol, Turkey has been keeping track of her GHG emissions since 2006. According to the national GHG emission inventory of Turkey, GHG (CO₂, CH₄, N₂O, HFC, PFC, and SF₆) emissions have increased 95% from 187 to 366.5 million tons CO₂ eqv. between 1990 and 2008. The CO₂ emissions for the same period increased from 141 to 297 million tons. In addition, the CO₂ emissions from electricity generation increased 234% from 30.3 to 101.5 million tons for the same period, covering, on average, approximately 30% of the total CO₂ emissions in Turkey. Consequently, the electricity generation between 1990 and 2008 in Turkey increased 244% from 57,543

to 197,839 GWh (UNFCCC, 2010). A reduction in electricity generation-associated CO₂ emissions can be achieved by increasing the usage of renewable energy sources, such as wind, geothermal, hydro, and biomass, for power generation.

There are currently only a few studies on the relationship between electricity generation and the associated CO₂ emissions in Turkey. These studies are generally national reports, such as the *National Inventory Report* (NIR) and the *First National Communication* submitted to the UNFCCC secretary due to certain responsibilities of Turkey. The methodology of calculating the GHG emissions in these reports depends on the Intergovernmental Panel on Climate Change (IPCC) approach, which is a top-down approach that does not differentiate IPCC default emission factors according to the low heating value (LHV) of each type of fuel.

The major objective of this study is to investigate the mitigation potential of CO₂ emissions from electricity generation using renewable energy sources over the next decade. To achieve this objective, CO₂ emissions from fossil-fueled power plants that ran between 2001 and 2008 are calculated, and then using these results, the country-specific emission factors for each fuel type are calculated. To the authors' knowledge, this is the first study that is based on calculating the total electricity generation-associated CO₂ emissions using data that cover all currently running power plants and that presents country-specific emission factors for Turkey for each fuel type based on current power plant data. These fuel-specific emission factors and the estimated amount of electricity that will be generated by the planned power plants are used to determine the electricity generation-associated CO₂ emissions in the next decade.

To date, efforts to investigate future electricity generation and the associated CO₂ emissions in Turkey have been limited. Studies conducted by the Ministry of Environment and Forestry (MoEF) (2006), Greenpeace (2009), and Turker (2008) are among those on the developing future electricity demand and the associated CO₂ emissions for Turkey. Different alternatives are used to supply the needed electricity demand and the associated CO₂ emissions in these studies; however, the official licensed and planned power plant data were not considered for calculating the supply side of the electricity demand and its associated CO₂ emissions, as is done in this study.

The power plant data used in this study are gathered from the National Load Distribution Center (NLDC) in Turkey (NLDC, 2009). The default emission factors and the calculation of the CO₂ emission methodology are based on IPCC Guidelines (IPCC, 2006). The low heating value of each fossil fuel and the thermal efficiency data of the fossil-fueled power plants in Turkey are obtained from various sources in the open literature. The estimated electricity demand between 2009 and 2018 is obtained from the Turkish Electricity Transmission Company (TETC, 2009). The planned and licensed power plant data with information on their completion are obtained from the Energy Market Regulatory Authority (EMRA, 2009).

2. Previous studies

Previous studies on determining the CO₂ emissions from the electricity sector, the fuel-specific emission factors, and a projection of the electricity generation-associated CO₂ emissions in Turkey are presented in this section.

One of the earlier studies on CO₂ emission inventory for Turkey was the “*Eighth Five Year Development Plan-Special Experts Report on Climate Change*” (SPO, 2000), in which a CO₂ emission inventory between 1970 and 2005 was calculated using the IPCC Tier-1 approach. A similar approach was used by Can (2006) to

determine CO₂ emissions from publicly owned fossil-fueled power plants. Another well-known study on CO₂ emissions is the “*National Inventory Report of Turkey GHG 1990–2007*” (TURKSTAT, 2009). The IPCC approach was again used in this report to calculate CO₂ emissions from the electricity sector.

In the studies mentioned above, the IPCC default emission factors were used without any adjustments for the fossil fuels used in Turkey to calculate electricity generation-associated CO₂ emissions. Because the quality of the fossil fuels, especially Turkish lignite, is not same as those used in other countries, CO₂ emissions calculated using these factors cannot wholly represent emissions from Turkey's fossil-fueled power plants.

To the authors' knowledge, there is only one study available on fuel-specific emission factors for Turkey, which was conducted by the IEA (2010). This study presents country-specific emission factors for coal, oil, and natural gas between 1990 and 2008 for Turkey and some other countries. There are other studies on emission factors in the literature, but they are not country specific and are not in time series.

The studies on the projection of CO₂ emissions from electricity generation in Turkey are also very limited. One of the first studies on CO₂ projection was the Ministry of Energy and Natural Resources' report (MENR, 2005), which included the results of the associated GHG emission projections based on four scenarios: a reference case, low growth, demand side management, and cogeneration. The estimation approach of calculating the associated CO₂ emissions is similar to that of the NIR (TURKSTAT, 2009). The pathway of these scenarios was policy oriented, not plan and program oriented. In addition, the planned and licensed power plants' data were not considered in these scenarios.

Another study is a report published by Greenpeace Turkey (2009), as given in Table 1. This study included the results of two scenarios on the projection of Turkey's electricity generation-associated CO₂ emissions. One of the scenarios of this study, the “Energy [R]evolution” scenario, is based on the potential of using renewable energy for electricity generation. However, only the technical potential of renewable sources is considered in this scenario.

Another study on CO₂ emissions projection was conducted by Say and Yucel (2006). These authors determined the relationship between the total energy consumption and total CO₂ emission in Turkey, and they estimated the total CO₂ emission using this relationship. A regression analysis was performed, and a strong relationship between total energy consumption and total CO₂ emission was found. While this study did include the total CO₂ emissions from the energy sector, it did not specifically deal with the electricity sector.

As stated above, to the authors' knowledge, there is no study that takes into consideration data of the licensed and planned power plants to estimate the associated CO₂ emissions from electricity generation for Turkey.

In this study, the electricity generation-associated CO₂ emissions up to 2019 are estimated by taking into account the current

Table 1
CO₂ emissions from electricity generation projections, million tons.

| Scenario name | 2010 | 2015 | 2020 |
|------------------------------------|------|------|------|
| MENR (2005) and MoEF (2006) | | | |
| Reference | 117 | 152 | 222 |
| Demand side management | 110 | 140 | 185 |
| Low growth | 107 | 137 | 163 |
| Cogeneration | 122 | 167 | 248 |
| Greenpeace Turkey (2009) | | | |
| Reference | 87 | | 161 |
| Energy [R]evolution | 82 | | 100 |

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