LONG-TERM BOTTOM-UP MODELLING OF TURKISH ELECTRICITY SECTOR

Esin Tetik[1], Isik University, Department of Industrial Engineering, Phone +90 216 528 7156, E-mail: esin.tetik@isikun.edu.tr
Kemal Sarica, Isik University, Department of Industrial Engineering, Phone +90 216 528 7153, E-mail: kemal.sarica@isikun.edu.tr

Overview

Turkey has declared a reduction of greenhouse gas emissions up to 21% from the business as usual by 2030 and signed Paris agreement as a developing country in COP21. In that manner, Turkey needs studies in consideration of climate change, yet no related academic study is can be found in the related literature. This study is the first model examines Turkish energy system using TIMES ***[1]*** modeling methodology to assess the future pathways of the system with detailed representation of the electricity sector under policy options.

With increasing energy demand, due to industrialization and increase in population, Turkey's future energy supply should be cautiously planned with respect to national resources, energy security and greenhouse gas emission rates and policies. The electricity sector is the key component of the energy system due to high dependence.

Fossil fuels that are primary reason of greenhouse gas emissions have a dominant share (88%) of energy consumption in Turkey. Natural gas as the dominant fuel accounted for 43.63% of total power generation in 2012. Other primary energy resources were coal (28.39%), hydro (24.16%), geothermal and the wind (2.82%), liquid fuels (0.68%), and renewable and waste (0.3%).

To increase the renewable energy resource’s share in power generation sector there are legal regulations in Turkey. The renewable energy law no: 5346 on the utilization of renewable energy sources for the purposes of generating electrical energy introduces incentives for domestic energy projects, providing feed-in tariffs for electricity from renewable energy sources. The aims of this law are increasing the share of electricity generated from the renewable energy resources, reducing the import dependency on fuels and environment protection by producing clean energy.

The focus of this study is to assess the potential CO_2 abatement within the economy caput with possible impacts on the whole national energy system. The economic efficiency of the law will be benchmarked with respect to the most widely accepted policy of CO_2 tax that generates the equivalent level of CO_2 reductions. Thus, the study will show the design issues of law with respect to monetary measures as well as sectoral impacts.

Methods

Bottom-up models evaluate on a detailed representation technological options and potentials for technical changes in the energy system. The connections represented as energy flows, a resources network and final users described in detail. Paths from the extraction of resources to final use are introduced and the technologies include technical and economic parameters. Bottom-up models represent demand as end-use demands such as lighting, cooling, and heating instead of energy types.

The TIMES as a bottom-up model generator aims to find the minimum cost energy system with balanced energy supply and demand by linear programming approach based on user-defined constraints. To model general energy system of Turkey, a TIMES database has been developed which covers the period 2012 through 2035 in three to five-year increments. In this study, annual residential demand is distributed using hourly time slices concept within TIMES framework. 24-hour time slices have been used to cover demand of electricity and primary energy resources at hourly, daily and seasonal time periods.

Characterization of existing and future technologies within the database is developed from public data sources and non-profit organizations.

Following the calibration and reference scenario formation based on expected economic growth and policies of Turkish economy and energy system, as a reflection of the renewable energy law no:5346, three government incentive scenario application has developed with feed-in-tariff for solar, wind and for both technologies. Additional

[1] PhD student at Istanbul Technical University

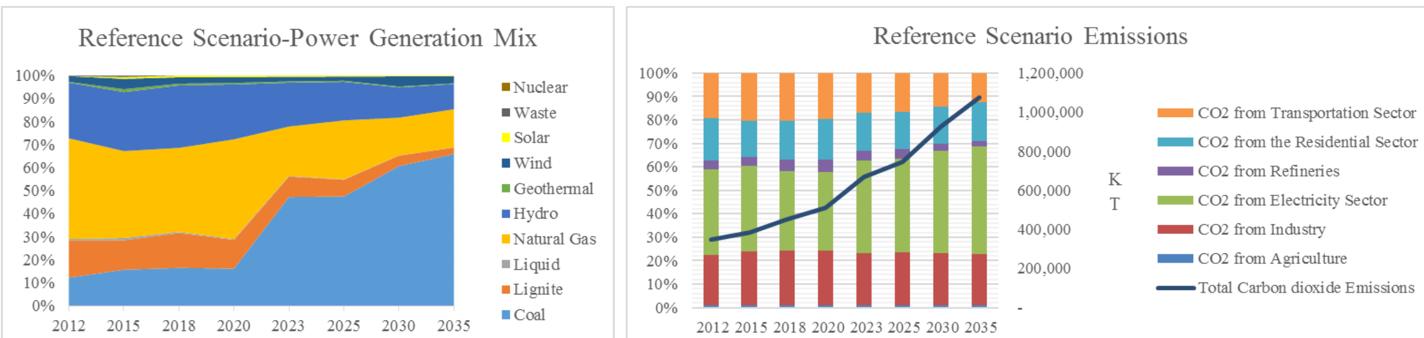
two optimization scenarios are developed to restrict electricity sector carbon dioxide emissions by the level of electricity sector carbon dioxide emissions of solar and wind feed-in-tariff scenario and to restrict whole energy sector carbon dioxide emissions by the level of total carbon dioxide emissions of solar and wind feed-in-tariff scenario.

Standard TIMES modeling framework does not inherit random nature of intermittent renewable energy resources directly. Instead, this intermittency/stochasticity is reflected to the energy system investment/operation strategies through the peaking reserve calculations. While controllable resources’ (natural gas, hydro) capacities are assumed to be 90% or above available for peaking demand consumption, intermittent resources capacities are accepted to be less than 50% according to technology type. Besides, intermittent renewable energy level reaches 26% level at maximum and declines to a steady-state after feed-in tariff expired in wind and solar FIT scenario, this model still can be effectively used for penetration of renewables. However, a stochastic TIMES model can be implemented for higher levels of intermittent renewable penetration levels for a more detailed analysis.

Results

In the reference scenario, as is shown in Figure 1, natural gas accounted for 43.7% share in 2012 and decrease to 21.4%, and hard coal becomes the dominant energy resource in 2023 with the share of 47.3% in the power generation mix. This changeover is preferable due to lower primary energy cost and electricity production costs of coal power plants comparing to the lignite and natural gas for the replacement of retired capacity within the system.

In the reference scenario, the total CO_2 emission is 349 Mton in 2012 and is almost doubled in 2023 and expected to reach 1,076 Mton which is three times of 2012 value in 2035. The highest share of the total CO2 emission arises from the electricity sector. In 2012, power generation sector covers the 36.5% of total CO_2 emission with 128 Mton CO_2 and increased to 46% as 494 Mton CO_2 in 2035.



(a) (b)

bvb

Figure 1: (a) Power generation primary energy mix (%), (b) Sectoral carbon dioxide emissions in reference scenario (KT)

The electricity production primary resource mix and its hourly distribution, technology capacities, electricity prices, carbon dioxide amounts, and unit CO_2 reduction costs are obtained for each scenario and results are analyzed and conclusions are drawn accordingly.

Conclusions

The wind and the solar incentive scenario has the highest system cost across all scenarios, when compared to the total carbon dioxide restriction scenario that has the same emission levels, cost of abatement is less costly under the equivalent emission tax scenario. Unit CO_2 reduction cost is 4 times higher in wind and solar incentive scenario than CO_2 tax scenarios in short-run and only wind incentive scenario converges to the CO_2 tax scenarios in the long-run. To conclude this scenario analysis, the current set of CO_2 abatement policy is found to be cost inefficient with respect to the taxation strategy. With respect to climate change direct CO_2 pricing such as ETS or direct emission tax may be a better strategy.

References

[1] IEA-ETSAP, «Overview of TIMES Modelling Tool,» [Online]. Available: http://iea-etsap.org/index.php/etsap-tools/model-generators/times.