Dr. Nihan Karali, Prof. Gürkan Kumbaroğlu, and Prof. Ilhan Or

THE ROLE OF ALTERNATIVE ENERGY USAGE IN THE TURKISH ENERGY SECTOR: AN ANALYSIS WITH THE BUEM ENERGY MODELING FRAMEWORK

Nihan Karali, Lawrence Berkeley National Laboratory, 1 Cyclotron Rd. MS 90, Berkeley, CA, USA,
Phone: +1 415 495 8185, Email: NKarali@lbl.gov
Gürkan Kumbaroğlu, Boğaziçi University, Industrial Engineering Department, 34342, Bebek, Istanbul, Turkey,
Phone: +90 212 359 7079, Email: gurkank@boun.edu.tr
Ilhan Or, Boğaziçi University, Industrial Engineering Department, 34342, Bebek, Istanbul, Turkey,
Phone: +90 212 359 6772, Email: or@boun.edu.tr

Overview

In today's dynamically changing and energy-sensitive environment, building comprehensive energy models and analyzing the system dynamics under alternative circumstances (scenarios) are essential. The world energy consumption demand is expected to increase considerably in the coming years as the result of population growth and economic development (EIA, 2011). Meeting rapidly growing demand at reasonable cost is a challenge, particularly for developing countries like Turkey. As of 2011 fossil fuels accounted for 88% of total primary energy supply (TPES) in the country. Naturally, meeting energy demand growth mainly by fossil fuels triggers a significant rise in greenhouse gas emissions. In addition, Turkey depends on imports for 79% of TPES including for practically all her oil and natural gas needs, and most of her coal needs. Therefore, policy-makers and researchers in Turkey are particularly interested in introducing alternative energy sources into the energy supply mix while striving to maintain stable prices at reasonable levels. It is essential to have alternative energy sources that can be substituted with fossil fuels so as to meet future energy demand sustainably.

In order to meet the increasing domestic demand for energy and reduce dependency on energy imports, various initiatives have been taken towards building Turkey's first nuclear power plant. An agreement was reached with Russia in 2010 to construct a nuclear power plant consisting of four reactors with a total capacity of 4800 MW. The plant is expected to start generating power by 2019. Following the agreement with Russia, Turkey has started a series of negotiations with China, South Korea and Japan for a second nuclear power plant. According to the statements made by the officials of the Ministry of Energy and Natural Resources, for energy diversification and security of supply, operation of three nuclear plants with a total capacity of 15,000 MW is aimed to be realized until 2023.

From this point of view, the objective of this study is to analyze the role of renewable energy sources and nuclear power as key alternatives in emission reduction and energy security policies. Modeling has been carried out by the Bottom-Up Energy Modeling (BUEM) framework, which is designed as a national energy supply-demand planning model for Turkey and capable of evaluating alternative energy supply strategies under cost minimization.

Methods

The BUEM framework (Karali, 2012) is designed as a new bottom-up, large-scale energy-modeling framework focusing on the mechanisms and relationships that mimic the energy sector as a whole. It is a straightforward, flexible, general purpose, linear optimization modeling system. All the complex relationships of producing, transforming, transmitting and/or supplying energy sources according to the demand mechanisms are represented with a deep technological detail. The objective is the minimization of the total energy system cost (which includes supply costs of energy sources, capital, operational and maintenance costs of technologies, various environmental costs, and any additional possible system costs) of an economy. The framework is run on a multi-period horizon while requiring partial equilibrium of the energy market. The levels and prices of the various energy sources are in equilibrium in each period. The model also ensures that the net total cost of supplying all levels of energy services are minimized, while satisfying a number of constraints, such as, system constraints (which are standard for any model application) regarding energy sources, demands, capacities, activities, electricity generations, emissions and other optional constraints such as user imposed policy constraints, including emissions restrictions, bounds on activities, capacities, and energy source supply levels.

In this study, detailed technical, sectoral, resource based parameters, and demand data regarding the Turkish Energy Sector are compiled within framework of the BUEM model. The planning horizon is set in 5-year time intervals extending from 2006 to 2051. Besides the Base scenario (describing the current conditions), the model has been run under three types of alternative scenarios:

1. **S-1**: "Nuclear Transition Scenario": In this scenario, nuclear energy, is made available as a relatively cheap power generation option. This scenario aims to provide insight into the differentiation in technology and supply selections under the phase-in of nuclear power as envisaged by policy-makers.
2. **S-2**: "Emission Limitation Scenario without Nuclear": In this scenario, overall emissions of the planning horizon are constrained by the emission levels observed in the S-1 scenario (from 2016 onwards), while letting the optimization system make its own selections on all other aspects without nuclear power. This scenario allows us to see the technology and supply selection differences between two scenarios (i.e., S-1 and S-2 scenarios) having different philosophies but the same emission levels, and reveals the economic implications of a nuclear transition under carbon constraints.
3. **S-3**: "Emission Limitation Scenario with Nuclear and CCS": In this scenario, emission restriction are set at the same levels as the S-2 Scenario; additionally, investment into nuclear and carbon capture and storage (CCS) technologies are allowed up to a limit. This scenario aims to see the contribution of nuclear and CCS technology investments on CO_2 emissions and abatement cost reductions.

Results

The scenarios used in this analysis are primarily designed for the purpose of decreasing the share of fossil fuels in TPES (thereby reducing CO_2 emission levels). Thus, we expect an increasing usage of efficient and renewable energy sources/technologies and nuclear power plants (if applicable). In each scenario, the results are focused on the penetration levels of renewable energy sources and nuclear power. Nuclear power plants are allowed in the S-1 and S-3 scenarios. This situation discourages the usage of renewable energy technologies in those scenarios. On the other hand, CCS technology availability in the S-3 scenario somewhat encourages more coal consumption (while at the same time reducing CO_2 emissions), thus reducing the need for renewable energy sources/technologies and nuclear power. Accordingly, in the S-3 scenario, where the CCS technologies are active, fossil fuel usage is expected to be higher. Besides the technological aspect, results are elaborated from an economic viewpoint revealing the cost of alternative policy options.

Conclusions

This paper presents a full-scale application of the BUEM framework on the Turkish energy sector and focuses on the penetration of renewable energy sources and nuclear power, and how energy supply profile, emissions and system costs change under the alternative scenarios defined previously. The results aim to suggest various useful policy implications for an environmentally and economically sustainable development of the country and provide long-term prospects for effective and applicable energy policy solutions.

References

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