Ecological Engineering 102 (2017) 589–595

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Turkey's energy planning considering global environmental concerns

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ARTICLE INFO

Article history:
Received 13 December 2016
Received in revised form 9 February 2017
Accepted 18 February 2017
Available online 21 March 2017

Keywords:
Air pollution
Greenhouse gases
Climate change
Power plant
Energy model
Environment
Turkey

ABSTRACT

Energy and energy policies are the main factors to determine the position of the country in the globalized world. By the year 2023 Turkey's main aim on the optimal energy distribution is to reduce the cost of energy production, create minimum effect on ecosystem and to use uninterrupted, environmentally friendly energy sources under the lights of UNFCCC and Kyoto protocol which was signed by Turkey also. By considering these facts; in this study a new mathematical energy model is proposed to design the future energy systems of Turkey and by solving it under this aim Turkey's 15-years electricity generation plan is obtained which is mainly used the renewable energy sources that has minimum effect on ecosystem. Turkey's energy need in 2030 is solved by a multi-objective mixed integer linear programming model under the Republic of Turkey Ministry of Energy and Natural Resource (MENR)'s objectives/goals by the year 2023 which are stated in the MENR's "Security of Energy Market and Supply Strategy" document and the scenario model optimizes simultaneously the objectives of energy production cost minimization, within the framework of the UNFCCC responsibilities of Turkey reduction on emissions of greenhouse gases, minimization of the use of power plants that use fossil fuels that has significant impacts on ecosystem, environment and causes of climate change.

1. Introduction

Since ecosystem is made up of organisms, environmental factors and physical/ecological processes; environmental factors and ecosystems have close relations. Since ecosystems are closely connected to their environment, any environmental change has an ecological consequences.

The increase in CO_2 concentration causes global and regional climate changes, i.e. GHG cause environmental changes. And the increase in greenhouse gases (GHG) concentration in the ecosystems (much of the greenhouse effect is caused by CO_2 emission) causes mutations in the cells of living species, ex. causes to alter the patterns of crop production. As a conclusion environmental changes cause significant effects on ecosystems. Therefore GHG concentration level is an important factor on environmental changes and the increase of it should be prevented/limited.

UNFCCC (United Nations Framework Convention on Climate Change) is an international environmental treaty/commitment that is developed to address the problem of global climate change and signed by the Parties to reduce their GHG emissions (UNFCCC, 1997). The Kyoto Protocol is an international agreement under UNFCCC and signed by parties in 1992 at the city of Kyoto/Japan that commits the industrialized countries to reduce greenhouse gas emissions to reduce greenhouse gases emissions.

The Kyoto Protocol is a legally binding agreement under which industrialized countries (168 countries including EU and Turkey) will reduce their emissions of greenhouse gas emissions by 5.2% compared to the year 1990 (UNFCCC, 1997). The Kyoto Protocol's goal is to decrease GHG emissions- i.e. carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, HFCs, and PFCs- between the years 2008 and 2012. EU counties target on the first period is minimum 8% reduction and USA's target is minimum 7% reduction on GHG emissions. The second commitment period of the Kyoto Protocol is signed in Doha on January 1st, 2013 under UNFCCC and the second commitment period is between the years 2013 and 2020. In the second commitment period of the Kyoto Protocol EU countries have agreed to meet minimum 20% reduction on GHG emissions compared to 1990.

Since the beginning of the Industrial Revolution, i.e. around 1750, human being have contributed to climate change and climate system have increased substantially. The dominant human activity affecting the climate change is GHG emissions from energy sector, i.e. combustion of fossil fuels. In order to save the World, all countries should implement action plan (energy system plan-

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http://dx.doi.org/10.1016/j.ecoleng.2017.02.033
0925-8574/

List of symbols

i	Power plant type
t	Year
xit	Supply amount of i^{th} power plant at the t^{th} year
PP	Set of power plants
PPe	Set of existing power plants
PPr	Set of power plants with renewable
PPf	Set of power plants with fossil fuels
ElCi	Unit electricity production cost of i^{th} power plant per kWh
PPICi	Installation cost of i^{th} power plant
PPOCi	Operating cost for i^{th} power plant per kWh
PPMCi	Maintenance cost for i^{th} power plant per kWh
PPRCi	Rehabilitation cost for i^{th} power plant per kWh
PPFCi	Fuel cost for i^{th} power plant per kWh
TLLAi	Transmission line loss amount/ratio of i^{th} power plant
TLICi	Transmission line installation cost of i^{th} power plant
TLLi	Transmission line length of i^{th} power plant
TLTICi	Cost of transformer/substation on the transmission line i^{th} power plant
IPi	Installation period of i^{th} power plant
NPPNit	The number of newly installed i^{th} power plant at the t^{th} year
CAPi	Maximum electricity production capacity of i^{th} power plant
Dt	Electricity demand amount in t^{th} year
PPNit	Used numbers of i^{th} power plant in t^{th} year
PPEio	Existing numbers of i^{th} power plant
ImEAt	Imported energy amount on the t^{th} year
ExEAt	Exported energy amount on the t^{th} year
ECOi	CO_2 emission amount for the i^{th} power plant per kWh
ESOi	SO_2 emission amount for the i^{th} power plant per kWh
ENOi	NO_x emission amount for the i^{th} power plant per kWh
EFFi	Efficiency factor of i^{th} power plant
tar	Electricity production target (percentage) = 0.30 (MENR, 2009)
DF	Discount factor = 0.10 (10%)
ExC	Unit export revenue
ImC	Unit import cost
RACOi	Annual CO_2 reduction amount of i^{th} power plant
RnCOi	Future revenues obtained from CO2 reduction per ton from the voluntary carbon market.

ning) to reduce GHG emissions that are causing climate change, i.e. changing in temperature, precipitation, winds, hurricanes, rising of the sea level and other indicators.

In the process of correct energy system planning, energy models are playing an important role (Pokharel and Chandrashekara, 1998) to critically analyze the true economic costs of energy, energy-environment-ecosystem-economy interactions, future demand–supply interactions, benefits, global warming and as a result environmental impact. The type of future energy systems used by the countries will affect the ecosystem, climate change and environment in the future and shape our World's future. Energy sector has great impact on climate change and it is one of the driving forces of the economic development of societies. In Turkey, the electricity generation from power plants in 2013 is based mainly on fossil fuels; natural gas 43.8%, hydraulic 24.8%, imported coal 12.3%, hard coal 1.4%, lignite 12.6%, wind 3.1%, biomass 0.3%, geothermal 0.6% and fuel oil 0.7% (MENR, 2014).

2. Materials and methods

2.1. Turkey's energy potential

According to MENR's high demand scenario in 2023 Turkey's energy demand will increase approx. 7.5% per year and will reach 538 TWh and in MENR's low demand scenario in 2023 it will reach 480 TWh. As per MENR's high demand scenario in 2030 Turkey's energy demand will reach 757 TWh and in low demand scenario it will reach 610 TWh.

End of 2013, Turkey's power plants installed capacity are as follows; coal 12,563 MW, hydro 22,289 MW, wind 2760 MW, solar 3.5 MW and geothermal 706.4 MW. MENR's aim is to use all of Turkey's domestic resources potential in the electricity generation until 2023 as per MENR's "Security of Energy Market and Supply Strategy" document (SEMSS) strategic document which is explained in detail in Section 2.2.

According to MENR; Turkey's assumed resources potential in electricity sector are summarized as follows: hard coal 11,000 GWh/year, lignite 118,000 GWh/year, asphaltite and oil shale 16,000 GWh/year, hydro 140000 GWh/year, wind 144,000 GWh/year, geothermal 15,200 GWh/year, biomass 93,000 GWh/year, solar 380,000 GWh/year.

2.2. Turkey's main energy goals in 2023

Turkey's energy goals & objectives in 2023 are stated in the MENR's "Security of Energy Market and Supply Strategy" document (SEMSS) which are the constraints of the mathematical model. The mathematical model of the study is formed by considering EU Directives, Kyoto protocol and the framework of UNFCCC (1997). In the study, Turkey's electricity demand variations, import and export increases are taken from MENR's data which is added into mathematical model as input.

The following objectives and constraints that are stated in the MENR's SEMSS strategic document (MENR, 2009) is considered in the mathematical model as constraints:

i MENR is aimed to increase the share of renewable energy sources, i.e. at least 30% of electricity production by the year 2023. In order to realize this objective in 2023 below steps will be implemented:
   - Solar power plant installed capacity will be 3000 MW (4,880 GWh) at the end of 2023.
   - Wind power plant installed capacity will be 20,000 MW (73,333.3 GWh) at the end of 2023.
   - Geothermal power plant installed capacity will be 600 MW (4,560 GWh) at the end of 2023.
   - Hydroelectric power plant installed capacity will be 36,000 MW (140,000 GWh) at the end of 2023.

ii By the end of 2023, it is aimed to produce 5% of the Turkey's total electricity generation from nuclear energy.

iii By the year 2023, it is aimed to use Turkey's all types of domestic coals to produce electricity.

iv Other than MENR's objectives stated in the SEMSS strategy document, private sector's objectives are also considered in the mathematical model:

a) EMRA(Turkey's Energy Market Regulatory Authority)'s objectives to produce electricity from natural gas is as follows: