Renewable Energy 50 (2013) 570–575

Contents lists available at SciVerse ScienceDirect

Renewable Energy

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

Vision 2023: Feasibility analysis of Turkey's renewable energy projection

Mehmet Melikoglu*

Department of Energy Systems Engineering, Bahcesehir University, Ciragan Caddesi, PK: 34353 Besiktas, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 20 September 2011
Accepted 23 July 2012
Available online 22 August 2012

Keywords:
Carbon tax
Energy consumption
Renewable energy
Sustainability
Turkish energy policy

ABSTRACT

Electricity consumption of Turkey at the year 2023 is estimated to be around 530,000 GWh. Turkey plans to supply 30% or 160,000 GWh of this demand from renewable energy sources according to the recently avowed government agenda Vision 2023. However, the current installed renewable energy capacity is around 60,000 GWh. Detailed literature analysis showed that only wind and solar energy potential in Turkey can solely supply this demand. In this study, two different scenarios were generated to analyse the cost and environmental impacts of supplying this demand. Scenario 1, which is derived from the official Vision 2023 targets, suggests supplying this demand from wind, solar, geothermal energy and hydropower. The total projected cost based on Scenario 1 is estimated to be $31.000 billion and annual greenhouse gas emissions of 1.05 million tonnes of CO_2 equivalent. According to Scenario 2 or the contrary setup it is assumed that the required demand gap could not be supplied from new renewable energy investments but equally from coal and natural gas. The projected cost is estimated to be around $8.000 billion and annual greenhouse gas emissions at appalling 71.30 million tonnes of CO_2 equivalent. Assuming carbon tax at the year 2023 to be $50 per tonne of CO_2 emitted, supplying the demand from renewable energy sources according to Scenario 1 would generate savings worth nearly $2.175 billion from environmental taxes annually. Thus, making the payback time of the renewable energy investments less than 15 years.

1. Introduction

Turkey is a developed country, member of The Group of Twenty (G20) major economies and a regional power. After the financial crisis of 2001, Turkey showed vast economic growth [1]. Coupling fast growing economy with vibrant young population, primary energy consumption increased almost 50%, between 2001 and 2008 [2]. After 7 years of high economic growth, the big global economic crisis of 2008 had a relatively small effect on the country's economy, when compared to other G20 countries. Turkish economy grew 9.2% by real gross domestic product (GDP) in 2010 and as of 2011, Turkey's economy seemed to shake the dust of the global economic crisis and started to sail new horizons on solid grounds. According to the recently avowed government agenda, Vision 2023, Turkey plans to be a member of ten major economies in the world with a gross domestic product at purchasing power parity per capita, GDP (PPP), of 2 trillion dollars at the year 2023 [3].

Economic growth has always been coupled with increasing energy consumption. If everything goes according to plan, Turkey's energy consumption will increase five times between 2000 and 2025 [4]. However, Turkey is a net energy importer, mainly fossil fuels. The energy import ratio is around 66% [5,6]. Based on the current energy market dynamics, if Turkish energy policy does not change with time, majority of this big energy demand at the year 2023 would be supplied from fossil fuels. The price of fossil fuels has been increasing continuously in the last decade and according to many scientists and energy experts will keep on increasing in the following years [7,8]. Fossil fuels cause major environmental problems and play a crucial role in global warming.

In order to eliminate these environmental problems and maintain a sustainable economic growth, Turkish government plans to produce 30% of Turkey's electricity demand at the year 2023 from renewable energy sources [9]. This impressive goal also matches with the energy consumption target of the European Union [10]. However, feasibility and justifiability of this ambitious plan have not been analysed yet. In this paper, economic and environmental impacts of producing 30% of Turkey's electricity demand at the year 2023 from various renewable sources are analysed in detail.

* Present Address: Department of Energy Systems Engineering, Atilim University, Kizilcasar Mahallesi, Incek-Golbasi, Ankara, Turkey. Tel.: +90 (0) 312 586 8568; fax: +90 (0) 312 586 8091.
E-mail address: mmelikoglu@atilim.edu.tr.

0960-1481/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.renene.2012.07.032

2. Electricity consumption in Turkey

Forecasting energy demand in emerging markets such as Turkey is one of the most important global policy topics, and most of the early studies regarding Turkey used various forms of economic models [11]. Electricity consumption in Turkey has been increasing almost exponentially since 1975, and according to many energy experts it will keep on increasing in the following decades due to high economic growth and increasing population. Turkish Ministry of Energy and Natural Resources has been using Model for Analysis of Energy Demand (MAED) to forecast medium- and long-term energy demand and Wien Automatic System Planning (WASP) to use MAED's results to develop optimum production and investment plans since 1984 [12]. The effectiveness of MAED applications to determine future energy consumption has been analysed by Ediger and Tatlidil, whom concluded a simple regression model, Holt Winters exponential smoothing method, seems to be a more sensible technique for Turkey [12]. Similarly, in this study, electricity consumption of Turkey till the year 2023 is estimated using an exponential empirical model shown in Eq. (1) and represented in Fig. 1. The net electricity consumption data, between 1975 and 2008, used for the estimation of model parameters are given in Table 1 [13].

$$E = E_0 \exp\left[k_1 (t - t_0)\right] \quad (1)$$

In Eq. (1), E is electricity consumption, TWh; E_0 is electricity consumption at the base year, TWh; t is time, years; t_0 is the base year, and k_1 is the model constant. Taking E_0 as 13.5 TWh and t_0 as 1975, the constant k_1 was calculated as 0.0765 using the modelling software SigmaPlot 11.0. As can be seen from Fig. 1, the mathematical model fitted seamlessly to the data with $R^2 > 99.1\%$. Using Eq. (1), Turkey's electricity consumption at the year 2023 is estimated as 530,000 GWh. This prediction matches fairly with the reported literature: 500,000 GWh [14] and 560,000 GWh [15], with an average of 530,000 GWh. Therefore, approximately 160,000 GWh of electricity must be produced from renewable energy sources at the year 2023 to meet the Vision 2023 targets. However, availability of such renewable energy potential in Turkey must first be verified.

3. Renewable energy potential of Turkey

In Turkey, share of renewable energy sources in electricity production reached almost 20% in the last decade [16]. However, more than 95% of renewable energy-based electricity is supplied from hydropower and share of other renewable energy sources in the country's annual total electricity production is less than 1%. This is very low when compared to other European Union countries and shows lack of diversity in energy supply. In Europe, use of hydropower in electricity production is not expected to further increase, since the majority of large hydro resources are already utilised and increasing demand for water and changing weather patterns may reduce the amount available for electricity production in the near future [17]. This is also the case for Turkey, and majority of new renewable energy investments is expected to focus in wind, solar, biomass and geothermal energy.

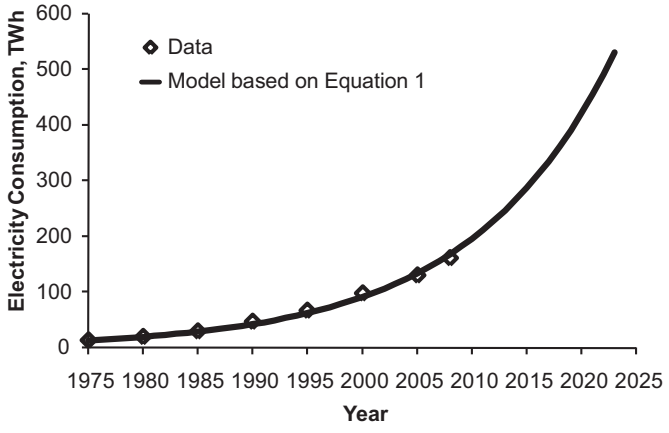

Fig. 1. Estimation of net electricity consumption in Turkey, TWh, between 1975 and 2023, using the mathematical model given in Eq. (1) and the data given in Table 1 [13].

Table 1
Net electricity consumption in Turkey, TWh, between1975 and 2008 [13].

Year	Net electricity consumption, TWh
1975	13.5
1980	20.4
1985	29.7
1990	46.8
1995	67.4
2000	98.3
2005	130.3
2008	161.9

3.1. Wind energy potential of Turkey

Feasibility studies confirmed that Turkey has a great potential for electricity production from wind energy [18]. Theoretically, Turkey's wind energy potential is estimated to be 160 TWh, annually [19]. Around 124 billion kWh of this potential is technically feasible, and for some specific locations, the net economic potential reaches about 14 billion kWh per annum [20]. The first wind power plant started operation in Turkey with an installed capacity of 1.5 MW in 1998, and the total installed capacity reached to 730 MW by the end of 2009 [21]. Large scale wind energy production, which is considered as an intermittent source, with high penetration into the grids may eventually require storage and backup systems to guarantee steady power supply [22]. As a result, wind energy must be utilised together with other renewable energy sources, such as solar or hydrogen energy hybrid systems in Turkey or elsewhere [23–25].

3.2. Solar energy potential of Turkey

Solar energy is abundant in Turkey, where the average solar radiation is 3.6 kWh/m^2 per day and the total annual radiation period is around 2610 h [26]. Theoretically, Turkey's annual solar energy potential is estimated to be 6150 TWh, and the annual economical potential is estimated to be 305 TWh [27]. Unfortunately, solar energy in Turkey is almost exclusively used for water heating by using roof top thermal solar systems. In terms thermal solar energy utilisation the total installed collector area capacity was 8.2 million m^2 in 2001, which makes Turkey one of the leading countries in the world [28]. However, at the beginning of the 21st century, Turkey's total installed solar electrical energy capacity was just around 300 kW for photovoltaic cells, which are generally used in communication stations for cell phone operators, sea lighthouses, highway lighting and fire observation stations [29,30]. Although, this shows the lack of solar energy investments in Turkey, it also pinpoints the availability of a new market for foreign and/or local investment with the opportunity of rapid market domination and growth.

3.3. Biomass energy potential of Turkey

In Turkey, electricity production from biomass is considered to be very promising. Biomass integrated gas turbine technologies, which offers high conversion efficiencies, are believed to be the future of biomass-based electricity production [31]. Turkey's main biomass production is based on wheat straw, wood and woody materials, cocoon shell, hazelnut shell, grain dust, crop residues and fruit tree residues [32]. The annual biomass energy potential is estimated to be around 32 Mtoe [33] or 372,000 GWh, and the total recoverable portion is estimated to be about 16.9 Mtoe or 197,000 GWh [30,34]. Turkey's first biomass-based electricity production project is under development in Adana province, with an installed capacity of 45 MW, and there are two other project, which are at the feasibility study stage, in Mersin and Tarsus with a total capacity of 30 MW [35]. In addition, each year more people are living in cities in Turkey and the amount of municipal solid waste generation increases almost exponentially. Therefore, electricity production from biogas at landfills could also bring a synergistic solution to biomass-based electricity production. Biogas production potential of Turkey is estimated between 1.5 and 2 Mtoe or between 17,750 and 23,250 GWh of electricity per annum, where the biogas energy potential of animal wastes ranges between 1271 and 9856 GWh, depending on types of biogas plants [30].

3.4. Geothermal energy potential of Turkey

Turkey is one of the five leading countries in direct use applications of geothermal energy and possesses 1/8 of the world's total geothermal potential; however, most of this potential is consistent of low enthalpy, which is not useful for electricity production but suitable for direct heating applications [36,37]. Turkey's geothermal energy is estimated to be 38,000 GW [29]. However, more than 31,000 GW of this energy is suitable for thermal applications [19]. Turkey's geothermal-based electricity production potential is estimated to be 2000–4500 MW [19,38] or up to 35,000 GWh per annum. According to the Ministry of Energy and Natural Resources Turkey's installed annual geothermal energy-based electricity capacity was 77 MW producing 436 GWh per annum in the year 2009 [39].

3.5. Hydropower potential of Turkey

Turkey's total annual hydropower potential is estimated to be 432 TWh, which is around 1.5% of the total hydropower potential of the world and approximately 14% of European hydropower potential [40]. Almost 50% of this potential is technically exploitable, and 28% or 124,000 GWh per annum is economically exploitable [30]. According to the General Directorate of State Hydraulic Works (DSI), Turkey's hydroelectric potential is around 54,000 GWh per annum as of 2012 [41], which is nearly 40% of the usable potential.

3.6. Renewable energy projection scenarios for Turkey in the year 2023

Current literature analysis pinpointed that Turkey's annual exploitable wind, solar, biomass, geothermal and hydroelectric energy potentials are 124,000 GWh [20], 305,000 GWh [27], 197,000 GWh [34], 35,000 GWh [19], and 124,000 GWh [30], respectively. Therefore, the required renewable energy-based electricity demand in Turkey at the year 2023, 160,000 GWh annually, can only be solely supplied from solar and biomass energy. Domination of a single energy system inexorably leads to unnecessary burden on a particular aspect of the environment, and can cause large scale environmental fatigue, which is the case for our current fossil fuel-based energy supply [42]. Therefore, to achieve low carbon objectives of renewable energy utilisation [43], power generation must be diversified in the Turkish electricity market. Turkish government's Vision of 2023 foresees some very ambitious renewable energy targets as can be seen from Table 2 [44]. Strangely, the Vision 2023 agenda does not contain any information about the capacity of biomass power plants. Considering Turkey's vast biomass potential omitting it in the official government renewable energy agenda is quite shocking. This is investigated in detail in the following sections.

The current annual hydroelectric capacity of Turkey is around 54,000 GWh [16,45]. It is assumed that with possible closures of some hydropower stations and commissioning of new hydropower plants, which are currently under construction this capacity will rise to 80,000 GWh [41] at the year 2023. Supplying nearly15% of Turkish annual electricity demand. For the hydropower plants which are currently under construction the required funds are allocated from the government budget. Therefore, new hydroelectric investments are omitted from the calculations. Assuming the capacity factors for solar, biomass, geothermal and wind power plants as: 25%, 85%, 90%, and 40%, respectively [46]; the required electricity generation from renewable energy sources by type to fulfil the Vision 2023 targets are calculated and reported in Table 3. Reverse engineering official capacity goals verified that without commissioning new biomass power plants Turkey could produce 30% of her energy demand from hydropower, wind, solar and geothermal energy if the planned plants are commissioned by the year 2023. This demand setup, as shown in Table 3, is denoted as Scenario 1. The cost and greenhouse gas emission savings based on Scenario 1 are calculated and analysed in the following sections.

As a fact, whether the renewable energy investments in Turkey are realized or not the electricity demand at the year 2023 must be supplied somehow. Considering this as a contrary scenario, it is assumed that if the renewable energy investments could not be realized until the year 2023, the gap in demand could be satisfied from new coal and natural gas power plants, 7.5% (40,000 GWh) each or 15% in subtotal plus 15% from hydropower plants, making 30% in total. This projection is denoted as Scenario 2. The average investment costs for various renewable and fossil energy sources, and their allocated greenhouse gas emissions are reported in Table 4 [47] and Table 5 [48,49], respectively. As a note of caution, in Table 5, the greenhouse house gas emission savings of coal and natural gas power systems are taken from the Intergovernmental Panel on Climate Change (IPCC) report for low carbon mitigation substitution option systems, which is planned to be in operation by the year 2023.

4. Estimation of renewable energy investments and allocated greenhouse gas emissions in Turkey according to Vision 2023 scenarios

The initial capital investment costs for renewable energy investments based on Scenario 1 are calculated and reported in Table 6. Amongst different sources, the lowest capital investment is

Table 2
Turkey's Vision 2023 renewable energy installed capacity targets, MW [44].

Source	Installed capacity, MW
Hydro	Full utilization
Wind	20,000
Solar	3000
Geothermal	600

Table 3
Required electricity generation from renewable energy sources by type, GWh, to fulfil the Vision 2023 targets, Scenario 1.

Source	Electricity generation, GWh
Hydro	80,000
Wind	70,250
Solar	6750
Geothermal	4750

Table 5
Average greenhouse gas emissions in various electricity generating systems, gCO_2/kWh, adopted from Refs. [48,49].

Source	Greenhouse gas emission, gCO_2/kWh
Wind, onshore	10
Solar	23
Biomass	26
Geothermal	38
Natural gas, combined cycle	404
Pulverised coal, advanced steam	710

required for geothermal energy at $1.300 billion. This is followed by solar energy at $9.700 billion. Calculations showed that the highest investment cost is required for wind energy at $20.000 billion. Thus, making the total investment cost for renewable energy-based supply at staggering $31.000 billion. Currently, initial investment costs of new generation coal and natural gas power plants are around $750 and $650 million per MW [50]. Assuming a 1000 MW coal or natural gas power plant producing 7 billion kWh annually, the initial investment costs for coal and natural gas power plants are calculated as $4.300 and $3.700 billion, respectively. Making the total fossil fuel-based capital investment according to Scenario 2 at $8.000 billion.

According to the results based on Scenario 1, over a time span of 12 years, around $2.500 billion of new renewable energy investment must be realized in Turkey, annually. However, considering the Turkish government's current plan to fully privatise the electricity market, it is a big question that who will pay this huge bill. Currently, guaranteed tariff for electricity produced from renewable energy sources is between 7.3 and 10.3 USA cent/kWh in Turkey [51]. This price range is low compared to other European countries, and Turkish government must adjust the purchase price of electricity produced from renewable energy sources at a reasonable rate and facilitate some other subsidies and/or incentives to realise the Vision 2023 goals.

In order to supply nearly 80,000 GWh of electricity at the year 2023; 56% of wind, 2% of solar and 14% of geothermal energy potential of Turkey must be allocated for power production. Although, for solar and geothermal energy these utilisation rates seem to be feasible, for wind energy in order to supply 70,250 GWh of electricity around half of the exploitable potential should be allocated. As an alternative, 35,000 GWh of electricity could be produced from biomass and the remainder 35,250 GWh could still be supplied from wind energy. The total estimated cost for this alternative scenario would be approximately $30.000 billion; and 28% of wind, 2% of solar, 19% of biomass, and 14% of geothermal energy potential of Turkey's would be allocated to fulfil the Vision 2023 targets. As stated above, considering Turkey's vast biomass potential the government officials should really think on incorporating biomass-derived power into the energy basket and update the goals of Vision 2023 agenda.

In order to reduce greenhouse gas emissions and tackle dependency on imported fossil fuels, the Turkish government also plans to generate a substantial amount of energy from nuclear power. The aim is to have 10,000 MW of electricity generating capacity installed, with 8 nuclear reactors, by the year 2023, with an additional 5000 MW under construction [44]. Currently, all the required administrative steps for the construction of two nuclear power plants, 4 reactors each, have been finalised by the government and if everything goes according to plan these reactors will be in operation in the centennial of the republic. The use of nuclear energy can help to reduce environmental pollution. Carbon dioxide emissions from nuclear power plants are generally by two orders of magnitude lower than those of fossil fuelled power plants [52]. However, there are general public concern over nuclear power in relation to the safety of reactor operation, nuclear waste disposal, and possible diversion of nuclear material capable of use in weapons manufacture [53]. After the Fukushima nuclear accident in 2011, due to a major earthquake, concerns over the safety of nuclear power plants have been raised worldwide and some countries have frozen their approvals of new nuclear power plant projects. In a political climate like this and considering Turkey's geographical location in a seismically active Mediterranean Earthquake belt [54] there is an increasing public concern in Turkey about the safety of the planned nuclear reactors. In addition, according to Sirin, Turkey has not evidently defined the role of government in development and acquirement of nuclear technology, has not developed a comprehensive policy for self-reliance in nuclear technology, and has not established proper legal framework and dispute settlement mechanisms so far [55].

On the other side, supporters of nuclear energy in Turkey claim that these power plants, when completed, would be landmarks for the economic and industrial development of Turkey, and socially assert her role as a regional power in the Middle East and Eastern Europe. Others also state that considering the instability in the Middle East, Turkey must have these nuclear power plants, no matter what the cost is, in that it could act as a psychological deterrent to potential treats. It could be argued that it would be unfortunate if political and security issues drove the decision, rather than scientific, environmental and economic assessments. Considering Turkey's huge energy demand in the year 2023 having nuclear power as a mix in the energy basket could provide some benefits. However, Turkey could achieve much more in terms of sustainability, environmental protection and technological enhancement if focuses her time, effort and money on renewable energy technologies. Time will show which is the wiser approach.

Turkey's greenhouse gas emissions have been increasing linearly between 1990 and 2009 [56]. This is believed to be related to economic growth and increasing population. Globally, energy sector accounts more than 70% of the greenhouse gas emissions [57], and 76% of Turkey's greenhouse gas emissions are generated from this sector [58]. Since, Turkey is an emerging market and

Table 4
Average investment costs for different renewable energy sources, $/kW, adopted from Ref. [47].

Source	Average investment cost, $/kW
Wind	1000
Solar	3250
Biomass	1700
Geothermal	2250

Table 6
Investment costs according to Scenario 1, billion $.

Source	Average investment cost, billion $
Wind	20.000
Solar	9.700
Geothermal	1.300
Total	**31.000**

Table 7
Annual greenhouse gas emission estimates based on Scenario 1, million tonnes CO_2 equivalent.

Source	Greenhouse gas emissions, million tonnes CO_2 equivalent
Wind	0.70
Solar	0.17
Geothermal	0.18
Total	**1.05**

reached to a developed country status recently, slightly higher carbon dioxide emissions from the global average are considered to be acceptable. Greenhouse gas emissions based on Scenarios 1 and 2 are calculated using average emission values for various electricity generating systems, reported in Table 5. The results are tabulated in Tables 7 and 8, respectively. According to the current assessment, solar-based electricity production is found to be the most environmentally friendly option with an annual greenhouse gas emission estimate at 0.17 million tonnes CO_2 equivalent. This is followed by geothermal energy at 0.18 million tonnes of CO_2 equivalent, then wind energy at 0.70 million tonnes of CO_2 equivalent. Summing up, the total annual greenhouse gas emissions of renewable energy systems supplying 30% of Turkey's electricity demand at the year 2023, based on Scenario 1, would be around 1.05 million tonnes of CO_2 equivalent. Comparing to the high economic cost, renewable energy-based electricity production has very low environmental pollution, as expected. On the other side, greenhouse gas emissions from fossil fuel-based supply of 30% of Turkey's electricity demand at the year 2023, based on Scenario 2, is estimated at staggering 44.50 million tonnes million tonnes of CO_2 equivalent. Showing the inadequacy of such systems at environmental protection even when they are so called low carbon mitigation systems.

Global warming is an undeniable fact and its damage on the environment and humans has become one of the most serious threats in the world; in order to reduce greenhouse gas emissions various policy methods have been implemented and among these methods carbon tax is considered to be a cost effective method in achieving a given reduction target and highly recommended by international organizations and energy experts [59]. Agostini et al. stated environmental taxation, or carbon tax as it is called now, can stabilize greenhouse gas emissions in the electricity generation of Europe at 1988 levels if high tax rates are assumed $100 per tonne of CO_2, however, the total emissions in all sectors would still keep on growing with only a decelerated rate [60]. Since Turkey is an associate member of the European Union the carbon tax would inevitably be implemented.

British Chancellor of the Exchequer George Osborne said the minimum paid by U.K. electricity producers will be £30 or around $47 per tonne of carbon dioxide by 2020. Assuming, this figure would be a constant value for all European Union member and associate countries, the adjusted carbon tax for Turkey in the year 2023 for electricity production is assumed to be $50 per tonne of CO_2 released to the atmosphere. Therefore, the carbon tax for renewable energy-based supply according to Scenario 1, and fossil fuel-based supply according to Scenario 2, would be $0.052 and $2.225 billion per annum, respectively. Thus, based on the carbon tax emission savings renewable energy investments based on Scenario 1 would have a payback period of less than 15 years.

Table 8
Annual greenhouse gas emission estimates based on Scenario 2, million tonnes CO_2 equivalent.

Source	Greenhouse gas emissions, million tonnes CO_2 equivalent
Coal	28.40
Natural gas	16.10
Total	**44.50**

5. Conclusion

Electricity consumption of Turkey is expected to reach 530,000 GWh at the year 2023. As an associate member of the European Union and according to the government agenda, Vision 2023, Turkey plans to produce 30% of this demand from renewable energy sources. This means supplying 160,000 GWh of electricity annually. Energy and environment are the most important topics of the 21st century and sustainable consumption of resources is gaining much more importance each day. In this study, economic and environmental implications of providing this amount of energy from renewable energy sources and fossil fuels are analysed based on two different scenarios. The results showed the utmost importance and benefit of renewable energy-based supply from both economic and environmental perspectives. This study can be further used as a foundation for the analysis of renewable energy investments in Turkey and their environmental impacts in the following years from both academic and economic perspectives.

Acknowledgements

I would like to thank to my mother and father for their continuous support and belief in me in difficult times.

References

[1] The world factbook Turkey. Central Intelligence Agency; 2011.
[2] Statistical review of world energy 2010. BP; 2011.
[3] AK party's 2023 Vision. Istanbul: Sabah Newspaper, Turkuvaz Media Group; 2011.
[4] Yüksel I. Energy production and sustainable energy policies in Turkey. Renewable Energy 2010;35:1469–76.
[5] Sayin C, Nisa Mencet M, Ozkan B. Assessing of energy policies based on Turkish agriculture: current status and some implications. Energy Policy 2005; 33:2361–73.
[6] Ceylan H, Ozturk HK. Estimating energy demand of Turkey based on economic indicators using genetic algorithm approach. Energy Conversion and Management 2004;45:2525–37.
[7] Heinberg R, Fridley D. The end of cheap coal. Nature 2010;468:367–9.
[8] Bassi AM, Powers R, Schoenberg W. An integrated approach to energy prospects for North America and the rest of the world. Energy Economics 2010;32: 30–42.
[9] Turkey's energy strategy. Republic of Turkey Ministry of Foreign Affairs; 2011.
[10] The EU's target for renewable energy: 20% by 2020. House of Lords, European Union Committee; 2008. p. 58.
[11] Ediger VS, Akar S. ARIMA forecasting of primary energy demand by fuel in Turkey. Energy Policy 2007;35:1701–8.
[12] Ediger VS, Tatlidil H. Forecasting the primary energy demand in Turkey and analysis of cyclic patterns. Energy Conversion and Management 2002;43: 473–87.
[13] Power installed of power plants, gross generation and net consumption of electricity. Turkish Statistical Institute; 2011.
[14] Ozturk HK, Ceylan H, Canyurt OE, Hepbasli A. Electricity estimation using genetic algorithm approach: a case study of Turkey. Energy 2005;30: 1003–12.
[15] Vision 2023 technology foresight project. Ankara: Energy and Natural Resources Panel Report, TUBITAK; 2003. 56.
[16] General energy balance for the year 2007 for Turkey (Mtoe). Republic of Turkey Ministry of Energy and Natural Resources; 2011.
[17] Verdesoto EG, McGarry D. A bright future for renewable electricity generation: if investment in grid and innovation is sustained. News Release, European Commission Joint Research Centre; 2009.
[18] Köse R. An evaluation of wind energy potential as a power generation source in Kütahya, Turkey. Energy Conversion and Management 2004;45:1631–41.
[19] Ogulata T. Energy sector and wind energy potential in Turkey. Renewable and Sustainable Energy Reviews 2003;7:469–84.
[20] Ediger VS, Kentel E. Renewable energy potential as an alternative to fossil fuels in Turkey. Energy Conversion and Management 1999;40:743–55.

[21] Celik AN. Review of Turkey's current energy status: a case study for wind energy potential of Çanakkale province. Renewable and Sustainable Energy Reviews 2011;15:2743–9.
[22] Sims REH, Rogner H-H, Gregory K. Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. Energy Policy 2003;31:1315–26.
[23] Sopian K, Ibrahim MZ, Wan Daud WR, Othman MY, Yatim B, Amin N. Performance of a PV-wind hybrid system for hydrogen production. Renewable Energy 2009;34:1973–8.
[24] Shakya BD, Aye L, Musgrave P. Technical feasibility and financial analysis of hybrid wind-photovoltaic system with hydrogen storage for Cooma. International Journal of Hydrogen Energy 2005;30:9–20.
[25] Panahandeh B, Bard J, Outzourhit A, Zejli D. Simulation of PV-wind-hybrid systems combined with hydrogen storage for rural electrification. International Journal of Hydrogen Energy 2011;36:4185–97.
[26] Sözen A, Arcaklioglu E. Solar potential in Turkey. Applied Energy 2005;80:35–45.
[27] Kaygusuz K. Prospect of concentrating solar power in Turkey: the sustainable future. Renewable and Sustainable Energy Reviews 2011;15:808–14.
[28] Balat H. Solar energy potential in Turkey. Energy, Exploration & Exploitation 2005;23:61–70.
[29] Balat M. The use of renewable energy sources for energy in Turkey and potential trends. Energy, Exploration & Exploitation 2004;22:241–57.
[30] Evrendilek F, Ertekin C. Assessing the potential of renewable energy sources in Turkey. Renewable Energy 2003;28:2303–15.
[31] Demirbas A. Production potential of electricity from biomass in Turkey. Energy Sources 2002;24:921–9.
[32] Sürmen Y. The necessity of biomass energy for Turkish economy. Energy Education Science and Technology 2002;10:19–26.
[33] Demirbas A. Electricity from biomass and hydroelectric development projects in Turkey. Energy, Exploration & Exploitation 2002;20:325–35.
[34] Balat M. Use of biomass sources for energy in Turkey and a view to biomass potential. Biomass and Bioenergy 2005;29:32–41.
[35] Demirbas A. Importance of biomass energy sources for Turkey. Energy Policy 2008;36:834–42.
[36] Akpınar A, Kömürcü MI, Önsoy H, Kaygusuz K. Status of geothermal energy amongst Turkey's energy sources. Renewable and Sustainable Energy Reviews 2008;12:1148–61.
[37] Hepbasli A, Ozgener L. Development of geothermal energy utilization in Turkey: a review. Renewable and Sustainable Energy Reviews 2004;8:433–60.
[38] Erdogdu E. A snapshot of geothermal energy potential and utilization in Turkey. Renewable and Sustainable Energy Reviews 2009;13:2535–43.
[39] General energy equilibrium in 2009. Republic of Turkey Ministry of Energy and Natural Resources; 2011.
[40] Kaygusuz K. Hydropower potential in Turkey. Energy Sources 1999;21:581–8.
[41] Turkey's hydroelectric potential and fundamental policy. Ankara: General Directorate of State Hydraulic Works; 2012.
[42] Li X. Diversification and localization of energy systems for sustainable development and energy security. Energy Policy 2005;33:2237–43.
[43] Grubb M, Butler L, Twomey P. Diversity and security in UK electricity generation: the influence of low-carbon objectives. Energy Policy 2006;34:4050–62.
[44] Turkey's energy sector. Ankara: Republic of Turkey Prime Ministry Investment Support and Promotion Agency; 2012.
[45] Kaygusuz K. Hydropower in Turkey: the sustainable energy future. Energy Sources, Part B: Economics, Planning, and Policy 2009;4:34–47.
[46] 2009 renewable energy data book. U.S. Department of Energy; 2010. 132.
[47] Erdogdu E. On the wind energy in Turkey. Renewable and Sustainable Energy Reviews 2009;13:1361–71.
[48] Sovacool BK. Valuing the greenhouse gas emissions from nuclear power: a critical survey. Energy Policy 2008;36:2950–63.
[49] Sims REH, Schock RN, Adegbululgbe A, Fenhann J, Konstantinaviciute I, Moomaw W, et al. Energy supplying climate change 2007: mitigation. In: Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA, editors. Contribution of Working Group III to the fourth assessment report of the intergovernmental panel on climate change. Cambridge, United Kingdom and New York, NY, USA: Intergovernmental Panel on Climate Change (IPCC); 2007. p. 253–322.
[50] Cost analysis in electrical energy. The Chamber of Electrical Engineers (EMO); 2011. p. 10.
[51] Sekercioglu S, Yilmaz M, Renewable energy perspectives in the frame of Turkey's and the EU's energy policies. Energy Conversion and Management. in press, Available online 17 April 2012, http://dx.doi.org/10.1016/j.enconman.2012.01.039.
[52] Abu-Khader MM. Recent advances in nuclear power: a review. Progress in Nuclear Energy 2009;51:225–35.
[53] Yim M-S. Nuclear nonproliferation and the future expansion of nuclear power. Progress in Nuclear Energy 2006;48:504–24.
[54] Bozkurt E, Mittwede SK. Introduction: evolution of continental extensional tectonics of western Turkey. Geodinamica Acta 2005;18:153–65.
[55] Sirin SM. An assessment of Turkey's nuclear energy policy in light of South Korea's nuclear experience. Energy Policy 2010;38:6145–52.
[56] GHG emissions (million tones CO_2 eq.). Turkish Statistical Institute; 2011.
[57] Anderson J, Fergusson M, Valsecchi C. An overview of global greenhouse gas emissions and emissions reduction scenarios for the future. Policy Department Economy and Science, DG Internal Policies, European Parliament; 2008.
[58] Sector based total greenhouse gas emissions in Turkey. Turkish Statistical Institute, TurkStat; 2011.
[59] Lin B, Li X. The effect of carbon tax on per capita CO_2 emissions. Energy Policy 2011;39:5137–46.
[60] Agostini P, Botteon M, Carraro C. A carbon tax to reduce CO_2 emissions in Europe. Energy Economics 1992;14:279–90.