

Assessment of Renewable Energy Resources in Line with the Targets Specified in the Turkish Strategic Plan and Application of the AHP Method

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Abstract-Turkey is an energy importing country and depends upon coal, oil, natural gas and hydraulic for its energy. Therefore, the government has prepared strategic plans for all alternatives including wind, solar, geothermal, biomass and other sources. One of these, the last 2015-2019 Strategic Plan, was put into force by the Ministry of Energy and Natural Resources. High energy demand is closely associated with industrialization, economic growth and population increase. Thus, recent projects also include energy efficiency measures to help reduce energy consumption. The energy sector has developed into a strategic area of vital importance. Although Turkey is a very rich country in terms of renewable energy sources and diversity of the country, the foreign energy dependence is about 75%. It is clear that Turkey needs to increase the share of new and renewable energy sources for sustainable development. In this study, a typical application is to choose an appropriate renewable source in Turkey. The software of Expert Choice supports the Analytical Hierarchy Process which has provided data to be analyzed statistically. It is suggested that the wind energy is in the first place and the biomass takes the last place.

Keywords AHP method, renewable resources, strategic plan, sustainable development, Turkey

1. Introduction

Turkey's national energy policy also includes the energy and use of indigenous energy sources. Parallel to the social and population growth due to the increasing trend in consumption of non-renewable energy resources; greenhouse gases are also major problems in meeting the quality requirements of emissions. Thus, additional efforts are still needed and the trend towards renewable energy sources will be supported quickly.

The Turkish energy policies are principally designed to support economic and social development. Turkey's natural conditions are suitable for use in renewable resources of energy such as hydropower, geothermal, wind, biomass, solar energy. It is estimated that the use of hydraulic and coal will reach full capacity in 2023, and therefore; the energy

demand will be primarily met by imported natural gas, coal and other resources.

In 2023, about 75% of the final energy demand and 67% of the electricity supply will be covered by coal, oil and natural gas. Oil and natural gas import dependency is significant. Primary energy sources are scarce and their uses generate energy at uneconomical prices and damages the environment. The use of fossil fuels and ash content, the use of older combustion technologies, and the inadequate use of air pollution control devices and inadequate insulation practices are still one of the main causes of air pollution problems caused by energy use. In addition to the emissions of carbon dioxide (CO₂) due to the burning of fossil fuels, toxic metals and radioactive substances can also be released.

Such wastes may be harmful to the environment and to health. It is expected that energy production will be around 20% by 2023. Thus, Turkey will be forced to import increasing amounts of energy. Turkey's energy supplies have been increasing in recent years, with attention paid to the benefits of energy efficiency that will also reduce pollution [1].

Turkey's energy strategy aims to meet the demand without hampering economic growth. The Energy Market Regulatory Authority (EMRA) in the Ministry of Energy and Natural Resources (MENR) regulates and supervises the electricity market and also monitors the progress of the renewable energy sector. To meet such an energy demand for new energy plans, Turkey needs to spend about 225-280 billion US dollars and 60 percent of this amount (135-168 billion US dollars) is expected to be used for machines [2]. Turkey has aimed to increase the productivity of public, private and foreign institutions through new investments and the rehabilitation of existing facilities. In the development of future industries in relation to the renewable resources, it is aimed to create jobs and reach out to Turkey's importance in energy and environmental goals.

Hydropower energy is an environmentally sensitive and economically sustainable resource. Dams are needed for irrigation and hydropower, but also for domestic water supply in large cities. However, dams may cause flooding or flood disaster, depending on local conditions. Emissions are expected to be lower than gas and coal power plants. The amount of methane (CH₄) and carbon dioxide (CO₂) produced depends on the decaying vegetation after the dam [3]. Hydraulic projects are in general improving the surrounding conditions and provide wetlands and various new developments around the reservoir. Hydropower plants can change the regime of sediment, reservoir area and exit zone. Greenhouse gas formation may occur [2]. Hydropower plants are accounted for approximately 20% of Turkey's installed capacity, but are regarded as harmful to the surrounding ecosystem by environmental groups, locals and pests in some areas. It shows that hydropower plants are least risky and least harmful compared to other power plant types in terms of air pollution, climate effects and risks [4].

The geothermal power plant produces sustainable and low emissions in comparison to the emission intensity of conventional fossil fueled plants. If pollutants (a gas mixture and toxic elements) are released, they may harm the environment. The chilled geothermal liquids should be injected underground using a suitable method. to reduce the environmental risk.

Wind energy has also a relatively small impact on environment in comparasion with the environmental impacts of fossil fuels. Although a wind farm covers a great deal of

land, many agricultural land uses are compatible with it. Ecological effects may or may not be important to the particular circumstances. It has an effect on the selection and operation of wind turbines. The noise generated by wind turbines can cause adverse health effects on people living in areas very close to wind turbines. Energy generated by renewable energy sources (excluding hydraulic) is mainly used for heating and baking. In this framework, as well as in Turkey's vision for 2023, the potential for economic power generation of wind and geothermal resources is about 20,000 MW and 4,500 MW respectively. The potential for economic geothermal heating is estimated at about 31,500 MW, which can meet 30% of all heating needs, but currently only 0.5% of the potential is used [5].

According to various sources of solar energy, the economic and electrical potential is estimated at 116,000 MW, and solar energy is currently only used for heating, which is less than 1% of the national energy production. Power generation by solar energy is not enough predicted in the current development plan. However, there are promising studies on installed solar collectors, photovoltaics (PV) and concentrating solar systems (CSP). As result, further research on renewable energies is needed [6,1]. It is estimated that renewable energy targets for installed capacity in Turkey are shown in Table 1.

Turkey must ensure low carbon and renewable energy policy objectives, energy efficiency research and adequate funding for the development of strategic design. The use of domestic renewable energy sources such as hydropower, wind, solar, geothermal, biomass should be increased in order to provide resource diversity[1].

Turkey's energy efficiency policies are continued by the 2007 Energy Efficiency Act and subsequent regulations. The law is based on four issues: Providing energy efficiency services between the administrative structure and the sectors; Education and awareness; Misuse penalties (usually fine); Incentives to increase energy efficiency and use of renewable energy..

The energy intensity of the Turkish industry is higher than modern standards. The energy intensity of the Turkish industry is, for instance, twice the average of OECD (Organization for Economic Cooperation and Development), four times that of Japan. Turkish industry has to increase energy efficiency in production and increase its share of energy mix in accordance with EU(European Union) regulations and standards of renewable energy [7].

Table 1. Renewable energy targets for installed capacity by years

Source	Year		
	2019	2023	2030
	(MW)	(MW)	(MW)
Hydro	32000	36000	36000
Wind	10000	20000	38000
Solar	3000	>5000	16000
Geothermal	700	>1000	1000
Biomass	700	1000	1000
Total	46400	61000	92000

Source : [1,7].

For sustainable and cost-effective manner and as long as they can help reduce the greenhouse gas emissions they produce, Turkey may want to consider broadening the usage of biofuels for transport. In Turkey, biomass is expected to play an important role in transport, heat and electricity. Some technologies, including biofuels and fuel cells, heat, transport and electricity markets in the long term also applies to Turkey. Biomass energy is one of the most important sources of renewable energy according to their potential and are expected to play an important role in Turkey. Due to its potential for agriculture and environment-friendly policies, Turkey is expected to have a great capacity for biofuels industry [8, 9].

The share of geothermal, wind and solar energy is expected to rise small but rapidly. Turkey has a very high geothermal growth over the last decade and has a still untapped potential for the use of geothermal energy for both heating and generation of electricity. On the other hand, generation of electricity from solar energy should be supported without delay.

Renewable energies (biomass, hydro and other renewable energies) are estimated to account for around 14% of the world's total primary energy demand by 2030. The share of biomass is assumed to decrease from 11% in 2006 to 10% in 2030, and hydropower total energy consumption will stabilize at about 2% [10].

In the long run, new technologies for renewable energies will also find smarter ways to reduce environmental costs, and energy systems will operate reliably and economically without waste elimination. As will be recalled, related projects will help to improve energy security, support clean energy transitions and enhance private sector financing and development of clean energy and energy efficiency investments [4].

2. Trends and Sustainable Development

Countries have become dependent on energy sources in terms of development and industrialization. Energy issues

affect international relations in different ways. It is important that the energy policies continue. Turkey's energy policy, energy security in the broadest sense, is to pursue strategic objectives such as economic growth and environmental protection. MENR is responsible for the preparation and implementation of energy policies, plans and programs in coordination with affiliates and other public and private organizations [11].

In the 2015-2019 Strategic Plan, 16 strategic goals and 62 strategic objectives were identified under a total of 8 strategic themes. The development of institutional and administrative capacity of ETBK has been structured on the themes that meet expectations of the industry's current needs in the field of energy and natural resources, and which are considered necessary for policy development. In Strategic Plan; all objectives, targets and strategies should be applied on the basis of environmental, economic and social sustainability principles. Sustainability is designed not to be a separate theme but to be a framework that covers all the themes. The themes and goals are given as follows [12]:

- Energy supply security (powerful and reliable energy infrastructure, optimum source diversity, active demand management)
- Energy efficiency and energy saving (using energy efficiency, advanced capacity for energy efficiency and saving)
- Good governance and stakeholder interaction (institutional capacity, using information technologies effectively, having high coordination power)
- Regional and international activity (an integrated regional energy market, a strong actor in international arenas)
- Technology, research and development and innovation (domestic technology in energy and natural resources , a result-focused research and development approach)
- Improvement of investment environment (competitive and transparent markets , improved investment processes)

- Raw material procurement security (non-energy raw material procurement security)
- Use of efficient and effective raw material (efficient and effective use of non-energy natural raw materials).

In addition, the targets mentioned in Strategic Plan are as follows:

- The share of renewable energy resources in primary energy and electricity supply will be increased.
- Extension of existing district heating systems will be ensured.
- It will be ensured that in-situ production is widespread and at least 1,000 MW of total consumption will be met from on-site production until the end of 2019.
- Completion of electricity energy production privatizations will be followed according to the plan to be announced.
- Governance and process structure for facilitating investments in energy and natural resources will be passed on.
- Alternative financing models will be developed to encourage investments in the energy and natural resources sector.
- National raw material strategy document including critical raw materials will be prepared for the country.

Although Turkey recently lived the fastest growth in energy demand among the OECD countries, energy use is

still low. According to the International Energy Agency (IEA), energy use will continue to grow at an annual growth rate of about 4.5% from 2015 to 2030 and will increase about twice in the next decade [7]. The potential for renewable energy resources is enormous as they can meet the world's energy demand many times over . The IEA estimates that demand for electricity could increase more quickly. The share of renewable energy is currently about 11% of domestic primary consumption in Turkey. The use of renewable resources such as hydro, wind, geothermal energy and solar energy is expected to increase to 30% of electricity needs by 2023 [8, 9]. In the International Energy Outlook (IEO) Reference case [12], it is indicated that world energy consumption increases by 28% while demand for energy is being increased in relation to strong economic growth drives between 2015 and 2040. Due to the economic growth, increased access to marketed energy and rapidly growing populations, the non-OECD countries play an important role in increasing energy demand. In the OECD countries, the amount of CO₂ emissions has generally declined since 2008 and these trends continue. On the other hand, in non-OECD countries, as the use of renewable resources increases the trends of the amount of CO₂ emissions associated with energy consumption continue to decline largely. With respect to global environmental issues, Turkey's carbon dioxide emissions have also grown along with its energy consumption. When the data of various sources is considered, the following tables can be created :

Table 2. Distribution of electricity generation by renewable energy resources in 2015

Source	Turkey(%)	OECD Countries(%)	World(%)
Hydro	25.65	13.20	16.34
Wind+Solar+Geothermal	5.83	7.49	4.91
Renewable+Waste	0.67	3.24	2.17
Total	32.15	23.93	23.42

Source : [5, 7]

Table 3. Distribution of installed capacity by renewable energy resources in 2015

Source	Turkey(%)	OECD Countries(%)
Hydro	35.36	18.0
Wind+Solar+Geothermal	7.35	16.0
Renewable+Waste	0.51	1.0
Total	43.22	35.0

Source : [5, 7]

Table 4. Electricity generation and shares by renewable energy resources

Source	Year					
	2015		2016		2017	
	%	TWh	%	TWh	%	TWh

Hydro	25.65	67.15	24.5	67.23	19.77	58.45
Wind+Solar+Geothermal	5.83	15.68	7.9	21.37	8.98	25.56
Renewable+Waste	0.67	1.35	0.9	2.37	0.94	2.79
Total	32.15	84.18	33.3	90.97	29.69	87.8

Source : [5, 7]

Table 5. Installed capacity and shares by renewable energy resources

Source	Year							
	2015		2016		2017		As Feb.2018	
	%	TWh	%	TWh	%	TWh	%	TWh
Hydro	35.36	25867.8	33.99	26681.1	33.3	27456.5	31.8	27456.5
Wind+Solar+Geothermal	7.35	5745.9	9.44	7404.7	11.2	9158	13.5	11576.3
Renewable+Waste	0.51	370.1	0.63	496.4	0.65	554	0.7	580.7
Total	43.22	31613.8	44.06	34582.2	45.15	37168.5	46.0	39613.6

Source : [7, 13]

Table 6. Turkey’s per capita electricity consumption targets

Year	kWh
2020	4800-5000
2023	5500-6000
2030	>7000
2040	>8000

Source : [7, 13]

Table 6 indicates that Turkey’s per capita electricity consumption may reach European Union’s average consumption towards 2030.

3. Application of the AHP Method

The Analytical Hierarchy Process (AHP) is a technique developed by Saaty as a model and used to solve multi-criteria decision making problems [14]. Thus, the AHP emerges as a mathematical method of assessing both qualitative and quantitative variables, taking into account the priorities of the group or individual, and also helping to improve the decision-making process. With this method, it is

aimed that the decision makers make more effective decisions. The steps required to resolve a decision making problem with the AHP are usually six stages, and the information that relates to each stage can be summarized as follows:

- Creating the problem statement and hierarchical structure
- Creating criteria binary comparison matrix
- Determination of percentage distribution of criteria
- Calculating consistency in binary criteria comparisons
- For each criterion, finding percent distribution of points at decision points
- Determination of priority order at decision points

Considering the EMRA’s strategic themes for Turkey, an analytic hierarchy process and its application is carried out by using the software of Expert Choice. In the hierarchical model, the main criteria are energy, economic and environmental targets. For the sub-criteria; energy targets are energy supply security, energy efficiency and energy saving, energy production potential, external dependency and raw material ; economic factors are indigenous technology features, research and development approach, investment costs, employment structure and environmental factors are effects to environmental quality , suitability for sustainability plans, and convenience in site selection. Solar, geothermal, hydropower, biomass and wind energy sources have been identified as alternatives of renewable resources. Criteria, sub-criteria and alternatives affecting the aim are indicated in a hierarchical order. In accordance with the Strategic Plan, a result appropriate to the AHP Method is identified and indicated in Table 7. The view of Table 7 is listed in Fig.1 as analyzed by the software of Expert Choice.

Table 7. Objective, criteria and alternatives determination table

Objective	Strategical Assessment of Renewable Energy Resources		
Main Criteria	Energy Factors	Economic Factors	Environmental Factors
Sub-criteria	Supply Security	Research and Development Approach	Effects to Environmental Quality
	Generation Potential	Indigenous Technology Features	Suitability for Sustainability Plans

	External Dependency and Raw Material	Investment Costs	Convenience in Site Selection
	Efficiency and Saving	Employment Structure	
Alternatives	Hydraulic, Wind, Solar, Geothermal, Biomass		

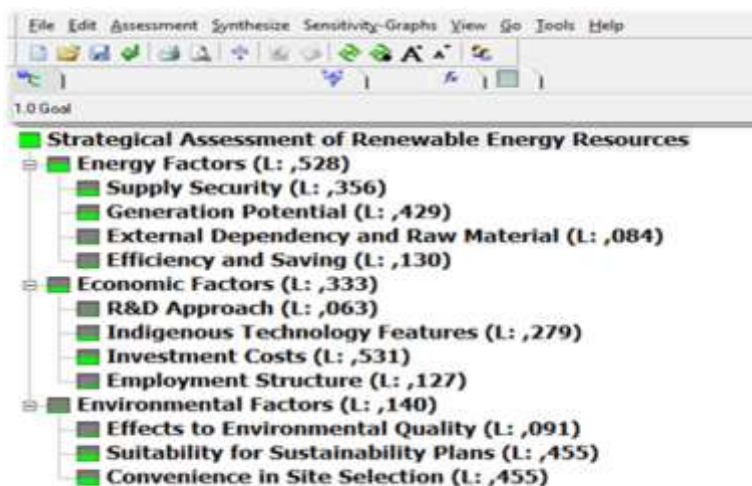


Fig. 1. View of strategical assessment of renewable energy resources

The evaluation and ranking for the main criteria are listed in Table 8 where priorities with respect to the main criteria as follows: energy factors (0.528), economic factors (0.333) and environmental factors (0.140).

Table 8. Priorities with respect to the main factors (inconsistency= 0.05)

Main Criteria	Priority
Energy Factors	0.528
Economic Factors	0.333
Environmental Factors	0.140

According to the results of the synthesis with respect to the main criteria; the assessments for the sub- criteria are given in Tables 9-11.

Table 9. Synthesis of energy factors (inconsistency= 0.04)

Sub - Criteria	Priority
Generation Potential	0.429
Supply Security	0.356
Efficiency and Saving	0.130
External Dependency and Raw Material	0.084

Table 10. Synthesis of economic factors (inconsistency= 0.04)

Sub - Criteria	Priority
Investment Costs	0.531
Indigenous Technology Features	0.279
Employment Structure	0.127
Research and Development Approach	0.063

Table 11. Synthesis of environmental factors (inconsistency= 0.00)

Sub - Criteria	Priority
Suitability for Sustainability Plans	0.455
Convenience in Site Selection	0.455
Effects to Environmental Quality	0.091

The sub-criteria of the main criteria of energy factors are as follows; generation potential, supply security, efficiency and saving, external dependency and raw material. According to the results of the analysis, the assessments for the alternatives are shown in Tables 12-15.

Table 12. AHP results of supply security factors
(inconsistency= 0.00)

Alternatives	Priority
Hydraulic	0.306
Wind	0.304
Solar	0.223
Geothermal	0.090
Biomass	0.077

Table 13. AHP results of generation potential
(inconsistency= 0.0096)

Alternatives	Priority
Wind	0.317
Hydraulic	0.295
Solar	0.179
Geothermal	0.109
Biomass	0.100

Table 14. AHP results of external dependency and raw material (inconsistency= 0.0096)

Alternatives	Priority
Wind	0.272
Hydraulic	0.252
Solar	0.183
Geothermal	0.166
Biomass	0.127

Table 15. AHP results of efficiency and saving
(inconsistency= 0.03)

Alternatives	Priority
Hydraulic	0.367
Geothermal	0.254
Wind	0.145
Biomass	0.120
Solar	0.114

The sub-criteria of the main criteria of economic factors are as follows; indigenous technology features, research and development(R & D) approach, investment costs, employment structure. According to the results of the analysis, the assessments for the alternatives are shown in Tables 16-19.

Table 16. AHP results of R&D approach
(inconsistency= 0.04)

Alternatives	Priority
Wind	0.380
Solar	0.265
Geothermal	0.140
Hydraulic	0.115

Biomass	0.099
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Table 17. AHP results of indigenous technology factors
(inconsistency= 0.00)

Alternatives	Priority
Wind	0.333
Solar	0.333
Hydraulic	0.111
Geothermal	0.111
Biomass	0.111

Table 18. AHP results of investment costs
(inconsistency= 0.00887)

Alternatives	Priority
Wind	0.262
Geothermal	0.262
Biomass	0.244
Solar	0.140
Hydraulic	0.091

Table 19. AHP results of employment structure
(inconsistency= 0.03)

Alternatives	Priority
Hydraulic	0.343
Wind	0.259
Geothermal	0.179
Solar	0.119
Biomass	0.099

The sub-criteria of the environmental factors are as follows: effects to environmental quality, suitability for sustainability plans, and convenience in site selection. According to the results of the analysis, the assessments for the alternatives are shown in Tables 20-22.

Table 20. AHP results of effects to environmental quality
(inconsistency= 0.05)

Alternatives	Priority
Solar	0.368
Wind	0.233
Hydraulic	0.183
Biomass	0.117

Table 21. AHP results of suitability for sustainability plans (inconsistency= 0.06)

Alternatives	Priority
Wind	0.249

Solar	0.249
Hydraulic	0.197
Geothermal	0.181
Biomass	0.124

Table 22. AHP results of convenience in site selection (inconsistency= 0.06)

Alternatives	Priority
Solar	0.324
Wind	0.244
Biomass	0.166
Hydraulic	0.155
Geothermal	0.111

The evaluation and ranking for the alternatives suggesting the overall priorities are listed in Table 23 where the wind energy is in the first place (0.281), followed by the hydro energy (0.223), solar energy (0.204), geothermal energy (0.157) and biomass energy (0.135) respectively.

Table 23. Overall priorities for the alternatives

Alternatives	Overall Priority
Wind	0.281
Hydraulic	0.223
Solar	0.204
Geothermal	0.157
Biomass	0.135

4. Conclusion

Non-renewable resources of energy are still very high importance and their contribution to the world electricity is approximately 70%. This percentage for Turkey is about the same as 70%. According to the projects planned by the MENR, Turkey's energy demand has increased rapidly over the past few years and will presumably continue to grow in the future.

Renewables are important in generating jobs, developing future industries and also in meeting Turkey's energy and environmental targets. By 2030, it is estimated that renewables will be meeting approximately 14% of the world's total primary energy demand. In the longer term, renewables have also the potential to make major contributions to Turkey's energy needs.

The strategic plans have been designed to increase the use of hydro, wind, geothermal, solar and biomass energy resources and Turkey aims to generate %30 of its electricity need from the renewable by 2023. On the other hand, in order to meet the growing electricity demand and avoid increasing dependency on imported fuels, the government has taken initiative for the integration of

nuclear energy into the Turkish energy mix. In order to meet the strategic targets of Turkey and ensure sustainable development, all the related projects should be completed within the anticipated time. If the improvements in the longer term are taken into consideration environmental costs will reduce and renewable energy and integrated power plants will operate both reliably and economically.

According to the AHP method considering both the EMRA's strategic themes and also all the main criteria and sub-criteria chosen in this study, the final preferences suggest that wind energy (28.1%) is in the first place while the others are respectively hydro (22.3%), solar (20.4%), geothermal (15.7%) and biomass (13.5%).

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