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The role of hydroelectric power and contribution of small hydropower plants for sustainable development in Turkey

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ABSTRACT

Turkey is a rapidly growing country regarding its economy and population and therefore has a large and continuously increasing energy demand. Turkey mostly meets its energy demand from imported fossil sources. However apart from petroleum and natural gas, Turkey has almost all kinds of energy resources and hence it would not need to meet its energy demand through import. In addition, Turkey has very large potential of hydraulic energy but to date only one-third of this significant economical potential could be used. This ratio seems insufficient when compared with that of European countries.

In this paper the role of hydroelectric power, its potential and its present status are investigated in detail for Turkey. Especially the small scale hydropower plant is emphasized as Turkey's renewable energy source. Furthermore the water resources of Turkey are examined.

1. Introduction

Turkey's geographical coordinates are 36°–42° north latitude and 26°–45° east longitude. It has a total area of 814,578 km^2 [1,2]. Turkey's geographical location makes it a natural bridge between the energy-rich Middle East and Central Asian regions.

Energy plays a vital role in the socio-economic development and in raising the standard of living. Turkey is a rapidly growing country where both its population and economy are expanding each year, resulting in a corresponding increase in its energy demand. This increasing demand has to be met to keep a sustainable development in the economy and to raise the living conditions of the people. Although Turkey has many energy sources, it is a big energy importer. Turkey has a lot of potential to supply its own energy, which could be harnessed in order to avoid this energy dependency. Additionally, Turkey is a country with an abundance of renewable energy sources and can essentially provide all energy requirements from its own indigenous energy sources [1].

The main indigenous energy resources of Turkey are lignite, hydro and biomass. Table 1 shows Turkey's present and future energy consumption (taken from Ministry of Energy and Natural Resources of Turkey) with respect to various resources [3].

Turkey's annual electricity demand in 2010, 2015 and 2020 is predicted to go up to 270 TWh, 410 TWh and 571 TWh, respectively [1,4]. It can be noticed from Table 1 that in order to meet the continuously increasing annual electricity demand of next 10 years, the indigenous renewable energy resources should be employed more instead of the non–abundant fossil sources to mitigate the energy dependence on foreign countries. This gives a strong motivation to explore the potential of hydropower as a renewable energy source, which has not been utilized sufficiently so far. It should be seriously considered as a major contributor to meet significant portion of all energy demand from now on.

Turkey has a total hydropower potential of 433 TWh that accounts for almost 1.1% of the total hydropower potential of the world and for 13.75% of European hydropower potential. Only 130 TWh of the total hydroelectric potential of Turkey can be used economically. By the commissioning of new hydropower plants, which are under construction, 43% of the economically usable potential of the country would be exploited. At present the hydropower energy is an important energy source for Turkey due to its useful characteristics such as being renewable, clean, and less impactful on the environment, as well as being a cheap and domestic energy source [5].

Hydropower is still the most efficient way to generate electricity. Modern hydro turbines can convert as much as 90% of the available energy into electricity while the efficiency of the best fossil fuel plant is only about 50%. Additionally, hydropower is an outstanding source to generate electricity in all over the world and will seemingly keep on growing especially in the developing countries [6,7]. While large dams have become much riskier investment, there still remains much unexploited potential for small hydro projects around the world.

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Table 1
Turkey's final energy consumption by resources.

Type of Resources (ktoe)	2006	2010	2015	2020
Hard coal	14,721	17,282	26,884	48,156
Lignite	11,188	18,001	24,190	32,044
Asphaltite	259	301	301	301
Oil	32,551	41,184	50,420	60,918
Natural Gas	28,867	37,192	44,747	51,536
Nuclear	0	0	8229	8229
Wind	11	421	571	721
Solar	403	495	605	862
Fuelwood	4023	3383	3075	3075
Animal and Vegetable residues	1146	1034	926	850
Geothermal (Heat)	1081	1750	2836	4584
Geothermal (Electricity)	330	330	330	330
Hydraulic	3556	4903	7060	9419
Growth rates (%)		29	35	31

In this paper, the role of hydroelectric power, its potential and its present status are investigated in detail for Turkey. Especially the small hydropower plant could be emphasized as a new renewable energy source of Turkey because it assists in increasing the economical usage of hydropower potential of Turkey.

2. Turkey's water resources and its potential

Contrary to the general thought, Turkey is not a rich country in terms of water resources. In Turkey, the gross water potential per capita was 3000 m^3 at the beginning of 2000. The annual per capita water potential is presently 1652 m^3. When Turkey is compared with the countries such as Israel, Jordan, Yemen which have a 150–400 m^3/year per capita water potential, Turkey seems to be "water-rich" in the region. But being a "water-rich" country requires having a water potential greater than 10,000 m^3/year water per capita. Thus, Turkey cannot be considered a "water-rich" country. Therefore, it is clearly understood from the gross water potential per capita values of Turkey, both at present and in the future, that some regions of the country will face water scarcity in drought seasons and Turkey will become a water-deficit country in the future [8–11].

Turkey has an annual average precipitation of 643 mm, but the distribution is quite uneven. This average annual precipitation corresponds to an average of 501 km^3 (501 billionm^3 (bcm)) of water per year. However, from the economic and technical points of view, the average exploitable water potential of the country is 112 km^3 per year [8–12]. Turkey's water potential is given in Table 2 [13].

Although Turkey has an adequate amount of water in general, it is not always in the right place at the right time to meet present and anticipated needs. Turkey is divided into 25 drainage basins in regard to the concept of hydrology, as given in Table 3 [11].

All drainage basins are shown in a Turkey map in Fig. 1. Annual average flows of these basins are approximately 186 km^3. The Euphrates and Tigris, among all basins, is the largest with about 185,000 km^2 of land area. Most of country's water potential lies in the southeast region (Euphrates and Tigris basin) with 28.5%, followed by Black Sea region with 13.3%, Mediterranean region with 10.8%, Marmara region with 4.5% and others.

Table 2
Water potential in Turkey [9].

	Precipitation (mm/m^2)	Aver. ann, prec. (billion m^3/yr)	Flow (billion m^3/yr)	Economically consumable (billion m^3/yr)
Domestic	643	501	186	95
Off country	–	–	7	3
Total	–	–	193	98
Underground	–	–	–	14
General total	–	–	–	112

Table 3
Turkey's drainage basins [8].

No	Name of basin	Rainfall area (km^2)	Annual average flow (km^3)	Share in total (%)	Annual average yield ($l/s/km^2$)
1	Meric-Ergene	14,560	1.33	0.7	2.9
2	Marmara	24,100	8.33	4.5	11
3	Susurluk	22,399	5.43	2.9	7.2
4	N. Aegean	10,003	2.09	1.1	7.4
5	Gediz	18,000	1.95	1.1	3.6
6	K. Menderes	6907	1.19	0.6	5.3
7	B. Menderes	24,976	3.03	1.6	3.9
8	W. Mediterranean	20,953	8.93	4.8	12.4
9	Antalya	19,577	11.06	5.9	24.2
10	Burdur	6374	0.5	0.3	1.8
11	Akarcay	7605	0.49	0.3	1.9
12	Sakarya	58,160	6.40	3.4	3.6
13	W. Black Sea	29,598	9.93	5.3	10.6
14	Yesilirmak	36,114	5.8	3.1	5.1
15	Kizilirmak	78,180	6.48	3.5	2.6
16	Konya(closed)	53,850	4.52	2.4	2.5
17	E. Mediterranean	22,048	11.07	6	15.6
18	Seyhan	20,450	8.01	4.3	12.3
19	Asi	7796	1.17	0.6	3.4
20	Ceyhan	21,982	7.18	3.9	10.7
21	Euphrates-Tigris	184,918	52.94	28.5	21.4
22	E. Black Sea	24,077	14.90	8	19.5
23	Coruh	19,872	6.30	3.4	10.1
24	Aras	27,548	4.63	2.5	5.3
25	Van lake	19,405	2.39	1.3	5
	Total	779,452	186.05	100	

The rivers in general have irregular regimes, and natural flows cannot be taken directly as usable resources. The average annual precipitation, evaporation and surface runoff greatly vary geographically. On the other hand, Turkey has 665,000 ha of inland waters, excluding rivers and small streams. There are 200 natural lakes, with a total area of 500,000 ha, and 775 dam lakes and ponds with a total surface area of 165,000 ha [11,14].

In view of the considerable variation in runoff in terms of seasons, years and regions, it is absolutely necessary for the major rivers in Turkey to have water-storage facilities to allow the use of the water when it is necessary. Consequently, priority has always been given to the construction of water-storage facilities. Significant progress has taken place in the construction of dams in the last 55 years that have elapsed since the establishment of the State Hydraulic Works (DSI) [15].

3. Role of hydroelectric power (generated from water resources) in Turkey for sustainable development

The obvious benefits of hydropower projects in Turkey or in any other country where hydropower potential exists abundantly, is associated with the generation of electrical power, which has the ability to both assist the sustainable economical development and increase the quality of life. Furthermore, they are labor-intensive during construction, as well as providing long term employment opportunities [14]. Another benefit of exploiting water resources is about environmental concern. Because it is a renewable, clean and green energy source, it is less harmful than fossil fuel sources causing dangerous gas emissions.

With the considerable contribution of few organizations such as DSI and others, hydropower development in Turkey has been carried out for about a century for different purposes, namely electricity generation, irrigation of regional lands, water supply for domestic and industrial utilization and flood control in the surrounding area. In order to be able to determine the role of