As a clean, sustainable and renewable energy—hydropower in Turkey

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Abstract. At the beginning of 2000's, Turkish government began privatizing some of its electricity generating and distribution networks, and allowing for more private construction and ownership in the sector. Owing to Turkey's regions, most of which are hilly, it can be possible to develop relatively higher heads without expensive civil engineering works, so that relatively smaller flows are required to develop for the desired power. In these cases, it may be possible to construct a relatively simple diversion structure and to obtain the highest drop by diverting flows at the top of a waterfall. There are intensive investigations to improve and development hydropower in Turkey. In recently, electricity demand has increased significantly and it is the fastest growing end-use of energy. Therefore, in the developing countries such as Turkey, the role of hydropower energy is very important. Because benefits of hydroelectric power make it an important contributor to the future world energy, particularly in the less developed countries. In this paper, as a clean, sustainable and renewable energy, hydropower and its benefits have been investigated in Turkey and some proposals which are to develop hydropower in this country have been presented.

1 Introduction

Energy is essential to economic and social development and improved quality of life in Turkey as in other countries. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially.

Hydropower contributes one-fifth of the world's power generation. In fact, it provides the majority of supply in 55 countries. For several countries, hydropower is the only domestic energy resource. Its present role in electricity generation is therefore substantially greater than any other renewable energy technology, and the remaining potential, especially in the less developed countries such as Turkey, is vast.

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While it is not a panacea, in that it is restricted to sites with available water and appropriate geomorphology, hydropower's flexibility and proven technology sets it apart from other renewable energy sources [1, 2].

2 Hydropower potential in Turkey

Turkey has a total gross hydropower potential of 433 GWh/yr, but only 125 GWh/yr of the total hydroelectric potential of Turkey can be economically used. So it can be said that, hydropower (especially small hydropower) potential should be used very widely and economically in Turkey.

Turkey's annual total gross, technically feasible and economically feasible hydropower potentials calculated by General Directorate of State Hydraulics Works (DSI) are 435, 215 and 128 tWh, respectively. 35 % of the economically feasible hydropower, total 45 155 gWh/year is in operation, 8 % (10 129 gWh/year) is under construction and 57 % (72 339 gWh/year) is being designed. Turkey has important hydropower potential as shown in Table 1 [3, 4].

Table 1. Hydroelectric potential in Turkey by river basins.

Name of river basin	Installed capacity (MW)	Average generation (GWh)	Energy Firm (GWh)
Susurluk	373.26	1336.00	955.00
Gediz	123.00	359	144.00
B. Menderes	278.80	1053.00	254.00
B. Akdeniz	596.79	2321.00	769.00
Antalya	1432.12	5262.00	1762.00
Sakarya	1177.54	2523.00	1515.00
B.Karadeniz	507.35	1747.00	995.00
Yeşilırmak	1270	5321.00	4171.00
Kızılırmak	2060.51	6181.00	4004.00
D.Akdeniz	1632.12	6039.00	3188.00
Seyhan	2048.29	8012.00	3847.00
Ceyhan	1663.20	5558.00	2824.00
Fırat	9672.93	38072.00	30096.00
D.Karadeniz	3462.55	11346.00	5288.00
Coruh	3178.90	10706.00	6217.00
Aras	834.92	2539.00	1775.00
Van Kapalı	62.06	260.00	157.00
Dicle	4969.88	16912.00	10641.00
Total Turkey	**35539.31**	**126109.00**	**78770.00**

In Turkey, the distribution of the hydro power plants, that are under design level, is presented in Table 2 according to their hydro capacity [5]. As can be seen, 30.34 % of all of the annual energy will be generated by SHP. There is 80 installed SHP in Turkey 5 % of which with medium head and 95 % with high head [6]. Being generally a mountainous country, Turkey's SHP potential is high. There is installed 80 SHP with 177 mW capacity. However, the remaining economically feasible potential is nearly 22 000 gWh/year [5].

Table 2. Distribution of under design hydro power plants according to their hydro capacity.

Classification	Number of HEPP	Total Capacity (mW)	Total Annual Energy (gWh)	Percentage of Total Annual Energy
<5 MW	139	312	1 568	2.17
5 to 10 MW	79	548	2 135	2.95
10 to 50 MW	186	4 595	18 244	25.22
50 to 100 MW	54	3 824	13 524	18.70
100 to 250 MW	36	5 527	18 179	25.13
250 to 500 MW	11	3 500	11 657	16.11
500 to 1000 MW	3	1 791	3 199	4.42
>1000 MW	1	1 200	3 833	5.30
TOTAL	**509**	**21 297**	**72 339**	**100**

In Turkey, development of small hydropower began in the year 1902. Since then, many small hydropower plants have been installed by government organizations, private sector, and local municipalities in many parts of the country [7, 8].

In Turkey, during last three decades the average annual increase of SHP capacity was 5-10%. As of 2002, the total development of SHP capacity that is accepted as small hydropower according to the Electrical Power Resources Survey and Development Administration which is less than 10 MW, in Turkey was 849,1 MW and total annual energy production was 3,623 (Table 3) [3, 5].

Table 3. Small hydropower development in Turkey.

Status of SHP	Number of SHP	Installed Capacity (MW)	Energy Generation (GWh)
In operation	70	175.4	654
Under construction	6	21.7	130
In final design	7	38.8	168
Infeasibility and pre-feasibility	120	613.2	2,671
Total	**203**	**849.1**	**3,623**

At the beginning of 2004, total number of SHP plants in operation throughout the country was 62, with a total installed capacity of 190 MW, about 1.5% of the total hydropower potential in Turkey [3]. Table 3 shows the summary of the total situation of SHP development in Turkey.

Total installed projects capacity of SHP is 2.45% and the total energy potential is about 2.96%, which have installed capacity less than 10 MW. At the end of 2004, about 96% of the all ready-exploited potential is from dams and HEPPs, and the remainder is from run-off river and canal SHP. Neglecting the geothermal, wind, and solar generation, about 65% of the electricity is produced by thermal power plants, and hydropower plants produce about 35% of the remaining electricity [9].

3 The advantages of small hydropower

Small hydropower plants combine the advantages of hydropower with those of decentralized power generation, without the disadvantages of large-scale installations. Small hydropower is [10]:

- A sustainable resource,
- An efficient resource,
- A secure resource,
- A clean resource and
- A renewable resource.

Small hydropower can be economically attractive, sometimes even offering the least-cost method of generating electricity. Small hydropower has the ability to generate electricity instantly, to supply both base and peak load generation, has a long life is easy to maintain and is highly reliable.

In addition, small hydropower development brings prosperity and raises the standard of living due to educational facilities, public health benefits, roads, electricity power and other infrastructure developments.

4 Cost of small hydropower

Small hydropower, especially the very small and the low-head plants, can normally only compete where allowance are made for the external costs associated with fossil fuels and nuclear power. Small hydropower projects are generally considered to be more environmentally favorable and sustainable than both large hydro and fossil fuel powered plants. So, small-scale hydropower is more economically competitive than small-scale fossil fuel/steam-electrical power.

The capital required for small hydropower plants depends on the effective head, flow rate, geological and geographical features, continuity of water flow, equipment such as turbines and civil engineering works. Making use of existing weirs, dams, storage reservoirs and ponds can significantly reduce both environmental impact and costs. Sites with low heads and high flows require a greater capital outlay, as larger civil engineering works and turbine machinery will be needed to handle the larger flow of water.

Apart from the investment and production costs, the other principal cost element is operation and maintenance, including repairs and insurance, which can account from 1.5-5% of investment costs. Both the production and investment costs differ considerably depending on the plant's head height.

5 Conclusion

Hydropower is a proven, well understood technology based on more than a century of experience. Its schemes have the lowest operating costs and longest plant lives. Upgrades and refurbishment of generating plant can readily extend scheme life. Hydropower plants also provide the most efficient energy conversion process. Modern plants can convert more than 95% of moving water's energy into electricity, while the best fossil-fuel power plants are only about 60% efficient. Hydropower also has the highest energy payback ratio. During the lifetime of a scheme, it can produce more than 200 times the energy needed to build it.

Turkey is an energy importing nation with more than 65 percent of our energy requirements met by imported fuels. Air pollution is becoming a significant environmental concern in the country. In this regard, hydropower, especially small hydropower (SHP) is

becoming attractive solution for clean and sustainable energy future of Turkey. Because Small hydropower can be successfully developed as long as it produces electricity at competitive prices and under conditions that respect the environment. On the other hand, small hydropower's main challenges relate to both economics and ecology.

Turkey as developing country has abundant SHP resources, which are economically feasible for development. In this country the majority of people live in rural areas.

In most rural areas of this country, because of lack of potable water, electricity and convenient transportation, the local economy remained underdeveloped and people were very poor. So, if it is developed of SHP projects in rural areas of this country, a lot of problems discussed above could be solved.

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