Chapter

Hydro Energy Potential for Electricity Generating on Selected Regions in Turkey

Ibrahim Yuksel, Omer Yuksek and Hasan Arman

Abstract

The aim of this chapter is to provide that hydroelectric energy production in Sakarya and Eastern Black Sea Basins which are selected as pilot region in Turkey. Hydroelectric energy has an important place in energy sector is generated from 26 main Basins in Turkey. Sakarya and Eastern Black Sea Basins are very important water resource in Turkey. In this study, hydro energy potential for electricity generating has been investigated in Turkey and hydro energy potential determined for the selected small streams in the Sakarya and Eastern Black Sea Basins by using hydro energy calculating methods.

Keywords: hydropower, energy potential, electricity generation, Sakarya Basin, Eastern Black Sea Basin, Turkey

1. Introduction

The Energy Market Regulatory Agency (EMRA) has license fee exemption for renewable energy investors and the Turkish Electricity Trading Company, TETAS, can provide buying guarantees to renewable energy, further supporting inward investment.

In Turkey, present and future installed electricity capacity by energy sources is given in the Table 1. According to the projection, the share of hydro capacity will be

| Energy source   | 2010 | 2012 | 2014 | 2016 | 2018 | 2020 |
|-----------------|------|------|------|------|------|------|
| Lignite         | 8280 | 8280 | 8280 | 8280 | 8280 | 8280 |
| Hard coal       | 560  | 560  | 560  | 560  | 560  | 560  |
| Imported coal   | 1840 | 3470 | 4680 | 4690 | 4690 | 4690 |
| Natural gas     | 14,840| 17,560| 18,400| 18,400| 18,400| 18,400|
| Geothermal      | 90   | 90   | 90   | 90   | 90   | 90   |
| Fuel oil        | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Other           | 29,382| 33,920| 35,970| 35,980| 35,980| 35,980|
| Hydropower      | 16,393| 19,880| 19,880| 21,094| 21,094| 21,112|
| Total (MW)      | 45,255| 53,320| 55,370| 56,594| 56,594| 56,612|

Table 1. Present and future installed electricity capacity by energy sources (MW) in Turkey.
Renewable energy sources

| Primary energy supply          | 2000   | 2005   | 2010   | 2015   | 2020   |
|-------------------------------|--------|--------|--------|--------|--------|
| Hydropower (ktoe)             | 2656   | 4067   | 4903   | 7060   | 9419   |
| Geothermal, solar and wind (ktoe) | 978    | 1683   | 2896   | 4242   | 6397   |
| Biomass and waste (ktoe)      | 6457   | 5325   | 4416   | 4001   | 3925   |
| Renewable energy production (ktoe) | 10,091 | 11,074 | 12,215 | 15,303 | 19,741 |
| Share of total domestic production (%) | 38     | 48     | 33     | 29     | 30     |

Table 2: Renewable energy supply in Turkey.

| Generation                  | 2000 | 2005 | 2010 | 2015 | 2020 |
|-----------------------------|------|------|------|------|------|
| Hydropower (GWh)            | 30,879 | 47,287 | 57,009 | 82,095 | 109,524 |
| Geothermal, solar and wind (GWh) | 109  | 490   | 5274  | 7020  | 8766  |
| Renewable energy generation (GWh) | 30,988 | 47,777 | 62,283 | 89,115 | 118,290 |
| Share of total generation (%) | 25 | 29 | 26 | 25 | 25 |

| Total final consumption     | 2000 | 2005 | 2010 | 2015 | 2020 |
|-----------------------------|------|------|------|------|------|
| Geothermal, solar and wind (ktoe) | 910  | 1385 | 2145 | 3341 | 5346 |
| Biomass and waste (ktoe)    | 6457 | 5325 | 4416 | 4001 | 3925 |
| Renewable total consumption (ktoe) | 7367 | 6710 | 6561 | 7342 | 9271 |
| Share of total final consumption (%) | 12 | 10 | 7 | 6 | 6 |

Figure 1. Share of sources in electricity generation in 2020.

highest with 37.4% and share of natural gas will be 32.6%. Renewable energy supply for at the present and in the future in Turkey is given in the Table 2 [1–7] and the share of sources in electricity generation in 2020 is given in the Figure 1.

2. Hydropower capacity and hydropower development in Turkey

In the last decade a lot of dams and small hydropower have been planned to build in Turkey in Eastern Black Sea and Sakarya Basins also. Most of them have been
already completed (for example Deriner Dam 669.60 MV in Artvin) and others under construction (for example Yusufeli Dam 558 MV in Yusufeli) in the eastern Black Sea region. Similarly, Adasu Small Hydropower (10 MV) has been completed and Akçay Dam (12 MV) under construction in Pamukova in Sakarya Basin.

On the other hand, in the last two decades a lot of dams and small hydropower (SHP) either completed or under construction in Turkey. State Hydraulic Works (DSI) provided equipment for the 140 MW Kigi project in Turkey, including three 46.6 MW turbines with pre-turbine gate valves, three generators of the same capacity, switchgear, and all other equipment for the turbine hall [8].

Figures 2 and 3 show hydropower global capacity, shares of top six countries and hydropower capacity and additions, top six countries for capacity added, 2013 respectively [8, 9].

3. Calculation method of hydroelectric potential

There are different methods for calculating hydroelectric energy. Since the amount of energy depends mostly on the water drop and water discharge values it is decided to use the method which is mentioned from some literatures [10, 11]. The method and it equations as follows:

\[ N = \gamma \ast H \ast Q \]  

The equation, \( N = \gamma \ast H \ast Q \), \( N = 9.81 \ast H \ast Q \ast \eta \) (\( \eta = 0.85\textnormal{–}0.92 \)) can be written for \( N \) and \( \eta \) is 0.85 the \( N \) is calculated as:
Renewable Energy

\[ N = 8 \times H \times Q \quad (2) \]

and then \( E \) is calculated as:

\[ E = N \times 24 \times 365 \quad (3) \]

In these equations:

- \( N \) = Power (\text{tms}) \ (1 \text{ tms} = 9.81 \text{ kW} = 13.3 \text{ HP}) and it goes to (kW, MV, GW)
- \( \gamma \) = Specific weight (t/m\(^3\))
- \( H \) = Water drop (head of water) (m)
- \( Q \) = Water discharge (m\(^3\)/s)
- \( E \) = Energy value of water resource (kWh, MWh, GWh)

4. Hydro energy potential for electricity generating on Sakarya and Eastern Black Sea Basins

4.1 Water resources and hydro energy capacity in Sakarya and Eastern Black Sea Basins

Out of 26 main basins, Sakarya and Eastern Black Sea Basins are very important about hydro energy potential in Turkey.

In 2016, Sakarya and Eastern Black Sea Basins have 63.358 km\(^2\) and 22.845 km\(^2\) area and 5.16 km\(^3\) and 16.46 km\(^3\) annual average flow respectively.

In this study, some streams which are observed their water discharge and the others hydraulics and hydrological characteristic were selected in the Sakarya and Eastern Black Sea Basins [12, 13].

When considered the alternative energy resources, hydroelectric generation is not generally achieved in Turkey, especially in Sakarya and Eastern Black Sea Basins. However, with some laws and regulations enacted, in many activities and opportunities such as construction, production and distribution related to investments carried out exclusively by the Turkish Government, but private sectors have not used enough these opportunities yet. Therefore, by using these facilities well, it will be possible for the private sector to close the energy gap in Turkey or to minimize it by evaluating the river resources in the region [14]. In this study, some small streams have been selected and their hydro energy potential determined for Sakarya and Eastern Black Sea Basins in Turkey.

4.2 Hydroelectric values for selected small streams in the Sakarya and Eastern Black Sea Basins

There are three types of potential which are gross (theoretical) potential, technical potential and economical potential [12, 15, 16].

Economical potential in generally depends on some geological and technical conditions such as geographical structure of basin, technical team and equipment facilities etc. To calculate of hydropower potential for selected streams in the Sakarya and Eastern Black Sea Basins the equations 1, 2 and 3 are used.

Hydroelectric Power (\( N \)) and hydroelectric energy (\( E \)) have been calculated by using this method. Hydroelectric power and hydroelectric energy values for selected streams in the Sakarya and Eastern Black Sea Basins are given in the Tables 3 and 4 respectively.
| Stream and station name | Water discharge (Q), m³/s | Water drop (head of water) (H), m | Hydroelectric power (kW) | Hydroelectric energy (GWh) |
|-------------------------|---------------------------|---------------------------------|--------------------------|----------------------------|
| Sakarya River - Dogancay | 121                       | 41                              | 4217                     | 364                        |
| Kocasu - Rustumkoy      | 179                       | 198                             | 3013                     | 260                        |
| Sakarya River - Aktas   | 7.15                      | 837                             | 5115                     | 442                        |
| Aladağ Stream - Karakoy | 13.3                      | 505                             | 5709                     | 493                        |
| Mudurnu Stream - Dokurcun | 7.75                     | 286                             | 1884                     | 163                        |
| Total                   | 19,938                    | 1722                            |                          |                            |

Table 3.  
Hydroelectric power and hydroelectric values for selected streams in the Sakarya Basin.

| Name of selected small stream | Average water discharge (m³/s) | Average water drop (altitude) (m) | Hydroelectric power (kW) | Hydroelectric energy (GWh) |
|-------------------------------|--------------------------------|----------------------------------|--------------------------|----------------------------|
| Iskefiye Stream               | 1.3                            | 535                              | 5,564                    | 48.74                      |
| Sana Stream                   | 1.5                            | 455                              | 5,460                    | 47.83                      |
| Orta Stream                   | 1.05                           | 285                              | 2,394                    | 20.97                      |
| Horyan Stream                 | 1.12                           | 230                              | 2,061                    | 18.05                      |
| Canakci Stream                | 2.36                           | 405                              | 7,646                    | 66.98                      |
| Yanbolu Stream                | 4.90                           | 60                               | 2,352                    | 20.60                      |
| Kalyan Stream                 | 2.45                           | 135                              | 2,646                    | 23.18                      |
| Fol Stream                    | 2.91                           | 155                              | 3,608                    | 31.61                      |
| Kucuk Stream                  | 2.34                           | 110                              | 2,059                    | 18.04                      |
| Durana Stream                 | 1.71                           | 90                               | 1,231                    | 10.79                      |
| Kadiralak Stream              | 2.90                           | 135                              | 3,132                    | 27.44                      |
| Manahoz Stream                | 4.98                           | 65                               | 2,590                    | 22.68                      |
| Baltaci Stream.               | 5.72                           | 75                               | 3,432                    | 30.06                      |
| Altintas Stream               | 4.11                           | 95                               | 3,124                    | 27.36                      |
| Acisu Stream                  | 1.56                           | 155                              | 1,934                    | 16.95                      |
| Akhisar Stream               | 1.60                           | 105                              | 1,344                    | 11.77                      |
| Solakli Stream                | 2.13                           | 105                              | 1,789                    | 15.67                      |
| Holo Stream                   | 2.65                           | 95                               | 2,014                    | 17.64                      |
| Askaroz Stream                | 6.26                           | 105                              | 5,258                    | 46.06                      |
| Kokasor Stream                | 4.03                           | 105                              | 3,385                    | 29.65                      |
| Pilahoz Stream                | 2.50                           | 95                               | 1,900                    | 16.64                      |
| Potomya Stream                | 0.84                           | 145                              | 974                      | 8.54                       |
| Hako Stream                   | 0.83                           | 105                              | 697                      | 6.11                       |
| Hongra Stream.                | 0.36                           | 105                              | 302                      | 2.65                       |
| Buyuk Stream                  | 1.56                           | 105                              | 1,310                    | 11.48                      |
| Vanazit Stream.               | 2.56                           | 70                               | 1,434                    | 12.56                      |
Conclusion

In this study it is shown that Turkey has abundant hydropower energy sources and great renewable energy potential and is keen to reduce its dependence on fossil fuels by increasing its use of renewable energy resources. The hydropower sector is a good example of the increasing interest in generation of electricity with renewable resources. It is expected that the Government will call for tenders for hydropower licenses.

It is well known that the environmental impacts of hydro plants are minimal compared with alternative resources. They make use of our renewable “green energy” resource, without causing pollution. It is not enough for governments to support the development of renewable energy technologies. They must also support their commercial application in the country.

On the other hand, hydroelectric facilities are very valuable resources in Sakarya and Eastern Black Sea Basins, which has a great potential due to meteorological, topographic, hydraulics and hydrological conditions. Using this potential, the economic situation of people most of whom are unemployed and poor and live rural areas will be significantly improved.

Since small hydropower plants are river type hydropower plants, small hydropower potential should be used in the country especially in the Sakarya and Eastern Black Sea Basins. Because river type power plants are superior than the other plants, this type plants have not only cost and operational features but also good environmental effects.

List of symbols and abbreviations

| Symbol | Description                  |
|--------|------------------------------|
| E      | energy value (kgm)           |
| N      | power (kgm/s)                |
| \(\gamma\) | specific weight (kg/m\(^3\)) |
| Q      | water discharge (m\(^3\)/s)  |
| H      | head of water drop (m)       |
| \(\eta\) | efficiency factor of turbine (%) |
S statistic
V variance
t_i the number of ties of length (m).
Z the statistic S is then standardized
d difference between ranks
n number of data
R rank value
S Sen's slope
x denotes the variable
i and j indices
b median $S_k$
TWh terra watt hour
GWh giga watt hour
MWh mega watt hour
kW kilo watt

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