

Water supply lines as a source of small hydropower in Turkey: A Case study in Edremit

S.Kucukali^{1,*}

¹ Cankaya University, Department of Civil Engineering, Balgat, 06530 Ankara, Turkey

* Corresponding author. E-mail: kucukali78@hotmail.com

Abstract: Hydropower has the highest share among the renewable energy sources of Turkey by 94% with a total installed capacity of 14,553 MW for the year 2009. Turkish government has based its energy policy on maximizing hydropower potential to be evaluated in next 15 years. In this context, private sector is expected to build hydroelectric power plants having a total capacity of 27,500 MW. Besides these hydropower plants, there is also a considerable hydropower potential in existing water supply systems. The most convenient locations for hydropower generation in water supply systems are water supply lines located before the water treatment or distribution network. In water supply lines, the excess pressure is dissipated by creating water jet in the pressure reduction tank. However, the excess pressure can be removed from the system by installing a hydro-turbine and it can be converted into useful energy by means of electricity. For a case study, the hydropower potential of the water supply system of Edremit in Turkey has been analyzed. There are 12 pressure reduction tanks along the water supply line of the city and the system has an electric energy potential of 4.08 GWh/year, corresponding to about 560,000 Euro/year economic benefit.

Keywords: Hydropower, Water supply lines, Turkey.

1. Introduction

The need for saving water and energy has grown as one of the world main concerns over the last years and it will become more important in the near future. Increase in oil and natural gas prices by 500% in last 15 years has made renewable energy sources become important than ever. Hydropower is a renewable energy source most widely used all around the world [1]. Installation of hydropower plants on water supply network has found a wide usage area in Europe (Table 1). For example, in Switzerland 90 small hydropower plants were installed on the municipal water supply network of the country (Table 2). The advantages of these facilities compared to river-type hydropower plants could be summarized as follows: (i) all civil works are present, which will reduce the investment cost in the order of 50% [2], (ii) the facility has no significant environmental impacts and it has a guaranteed discharge through the year, (iii) the generated electricity is used in the water supply system and the excess electricity is sold to the government, (iv) there is no land acquisition and significant operating costs [3]. In this context, this study aims to show the possible benefits of the installation of a water turbine in water supply line. This could be an alternative clean energy solution to reduce the consumption of energy supplied by the national electric grid mostly fed by fossil fuels and to induce the minimization of CO₂ emissions to the atmosphere. In the present study, utilization of the hydropower plants in existing water supply systems has been discussed. As a case study, the hydropower potential of the water supply system of Edremit, Turkey has been analyzed in detail.

Table 1. Some examples of hydropower plant installation on water supply lines in Europe. Data source: [1]

Plant Name	Country	Design discharge (m ³ /s)	Gross head (m)	Output (kW)	Production (MWh/year)
Vienna Mauer	Austria	2	34	500	364
Mühlau	Austria	1.6	445	5750	34000
Shreyerbach	Austria	0.02	391	63	550
Poggio Cuculo	Italy	0.38	28	44	364
La Zour	Switzerland	0.30	217	465	1800

Table 2. Multipurpose schemes in Switzerland: operating and remaining potential. Data source: [1]

Water network type	Potential type	Number of sites	Output (MW)	Production (GWh/year)
Drinking water	Operating	90	17.8	80
	Remaining	380	38.9	175
Treated waste water	Operating	6	0.7	2.9
	Remaining	44	4.2	19

2. Methodology

A typical water supply system is composed of water source and storage, supply lines, water treatment plant, storage tank and distribution network (Fig. 1). The objective of water supply systems is to guarantee the delivery of adequate amount of good quality water to the inhabitants of the region. However, energy is needed to achieve this objective which requires operate water pumping and operation of treatment plants. The supply lines transport the water from storage to treatment facilities and treated water to storage tanks. It should be noted that the supply lines have limitations for pressure. For example, In Turkey, the static pressure should be in the range of 20-80 m head [4] and if the upper limit of the pressure is exceeded along the pipe line, pressure reduction valves or tanks are used to dissipate the excess pressure head. Based on the estimations of Bank of Provinces, there is a 30 MW hydropower potential in the existing pressure reduction and storage tanks in Turkey.

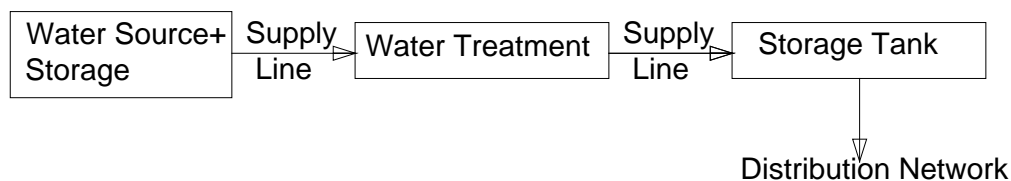


Fig. 1. Flow diagram of a typical water supply system

The shares of water supply sources in Turkey, with a capacity of 5.16 billion m³ in 2006, are as follows: 36% dam reservoirs, 27% groundwater reservoirs, 27% springs, 6% rivers and 4% lakes [5]. The domestic water demand is expected to increase from 6.2 billion m³ in 2007 to 26 billion m³ in 2030 (Fig.2). There are totally 43 municipal water supply dams in operation and the distribution of these dams across the country is shown in Fig.3. The municipal dams

are distributed over 23 cities and the most of them are in the big cities like Ankara, Istanbul and Izmir [6].

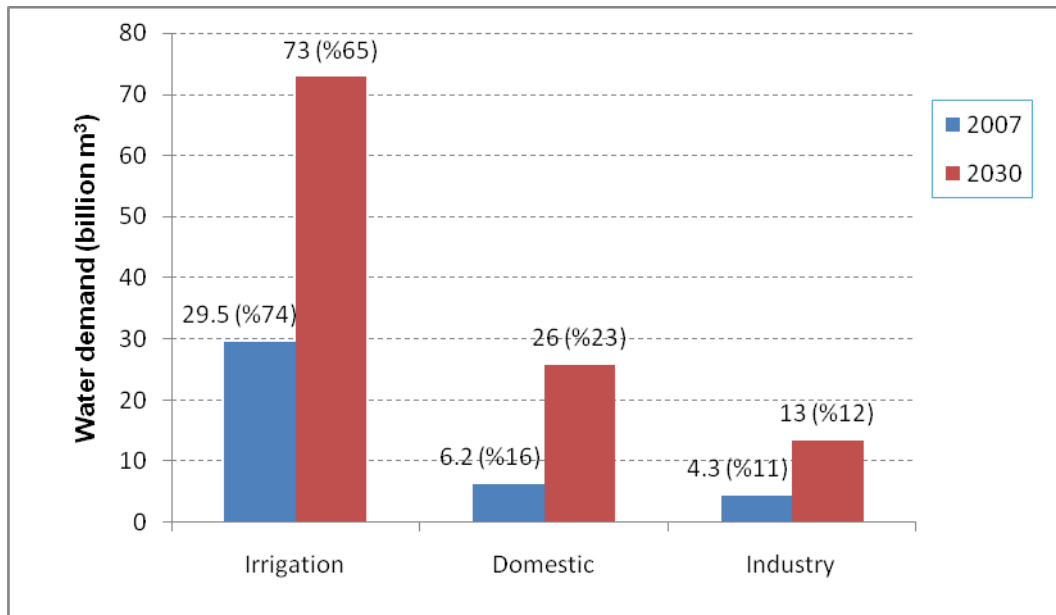


Fig. 2. Water demand of Turkey by sectors for 2007 and 2030 (projection by DSI)

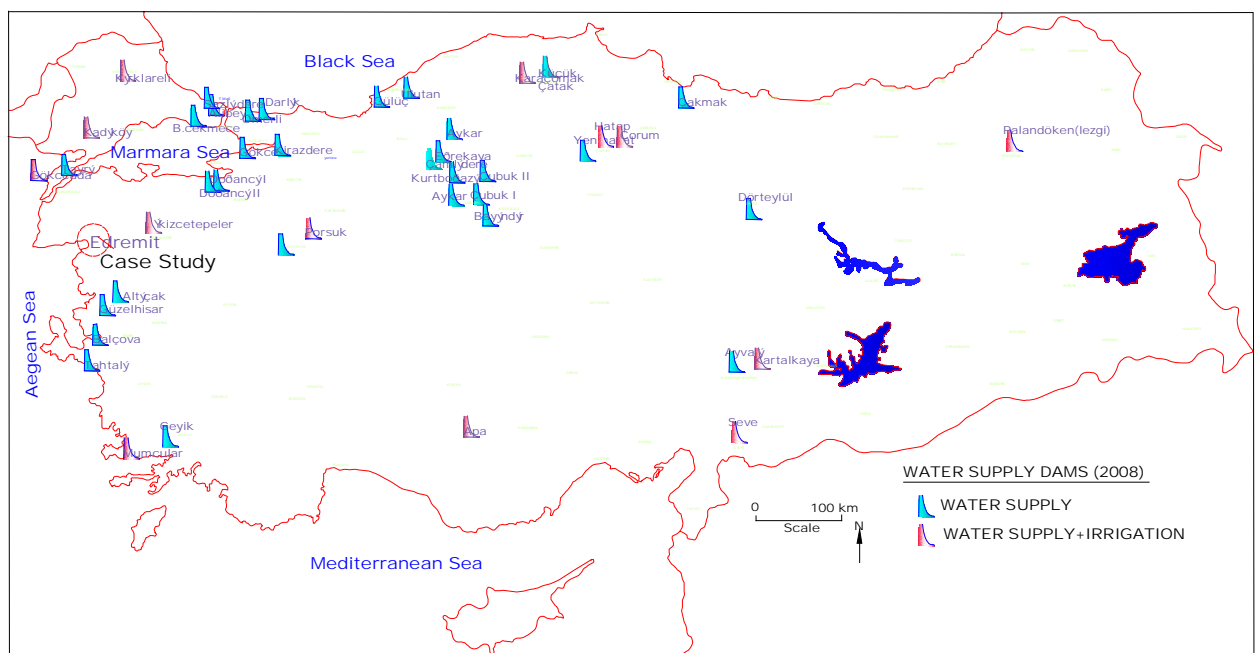


Fig.3. Municipal water supply dams in Turkey by 2008 and the location of the case study.

Hydro-turbines convert the water pressure into mechanical shaft power, which can be used to drive an electricity generator, or other machinery. The available power is proportional to the product of pressure head and water discharge. Modern hydro-turbines can convert as much as

90% of the available energy into electricity. The installed capacity P (kW) of a hydropower plant is calculated from

$$P = \gamma \times Q \times H_n \times \eta \quad (1)$$

where γ is the specific weight of water, Q (m^3/s) is the discharge, H_n (m) is the net head (m), η is the sum of the turbine and generator efficiency. The annual energy generation E (kWh/year) of a hydropower plant is obtained from

$$E = P \times t \quad (2)$$

where t is the operating hours in a year. The most convenient locations for hydropower generation in water supply systems are water supply lines located before the water treatment or distribution systems. In water supply lines, using the Bernoulli energy equation between sections 1 and 2 (Fig.4) and employing a velocity head correction factor of 1 gives

$$\frac{U_1^2}{2g} + \frac{p_1}{\gamma} + z_1 = \frac{U_2^2}{2g} + \frac{p_2}{\gamma} + z_2 + \Delta H \quad (3)$$

where, U is the average velocity, p is the pressure, z is the elevation above an arbitrary datum, g is the acceleration of gravity, ΔH (m) is the hydraulic head loss between 1 and 2. The head loss occurs because of the frictional and local energy losses. The velocity head is constant through the supply line and the excess pressure head equals to

$$\Delta H = \frac{p_1 - p_2}{\gamma} + (z_1 - z_2) \quad (4)$$

In water supply lines, the pressure head increases rapidly in the system where the elevation difference between two points is high and the excess pressure head is dissipated in pressure reduction tanks. In these structures, the pressure head is dissipated to atmospheric pressure by creating water jets. However, the pressure head could be removed from the system by installing a hydro-turbine. Then, the excess energy will be converted into useful energy by means of electricity.

3. Edremit Water supply System: A Case Study in Turkey

Edremit is situated on the north Aegean coast of Turkey (Fig. 4). Edremit's economy relies largely on the production of olives and tourism. The water used in the city is supplied from a spring located at Mount Ida and the supply line has an elevation range between 80-868 m. Water is carried at a rate of $0.16 \text{ m}^3/\text{s}$ by a polyethylene pipeline which has a diameter of 450 mm and a length of 32.7 km (Fig.3). There are 12 pressure reduction tanks along the supply line to regulate the pressure of the flow. The pressure heads of the pressure reduction tanks are presented in Table 3.

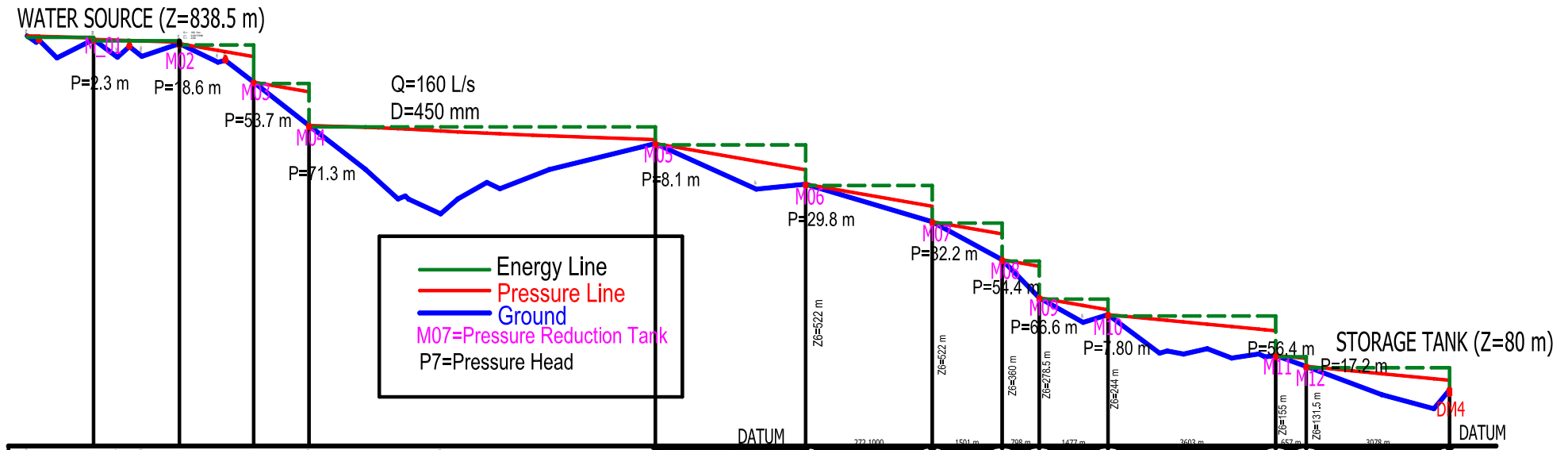


Fig.4 Water supply system of Edremit and the variation of pressure along the supply line

Table 3. Hydropower design characteristics of pressure reduction tanks of Edremit

Tank No	Head (m)	Discharge (m ³ /s)	Output (kW)	Energy (kWh/year)	Benefit (Euro/year)
1	2.3	0.16	3	24,524	3,433
2	18.6	0.16	25	198,321	27,765
3	53.7	0.16	72	572,571	80,160
4	71.3	0.16	95	760,229	106,432
5	8.1	0.16	11	86,365	12,091
6	29.8	0.16	40	317,740	44,484
7	32.2	0.16	43	343,329	48,066
8	54.4	0.16	73	580,035	81,205
9	66.6	0.16	89	710,116	99,416
10	7.8	0.16	10	83,167	11,643
11	56.4	0.16	75	601,359	84,190
12	17.2	0.16	23	183,393	25,675

The excess pressure heads are dissipated to the atmospheric pressure by creating free water jets in these tanks (Fig. 5). However, the excess pressure can be removed from the system by installing a hydro-turbine and it can be converted into useful energy by means of electricity (Fig.6). The pressure head of the pressure reduction tank was taken as design head for the hydro turbine installation and the design discharge is selected as 0.16 m³/s (Fig.7). The electricity price is about 14 Eurocent/kWh in Turkey for the May 2010 and the price was used in determining the economic benefit of the hydropower schemes. The operation of water supply system already exists. So there will be no extra operation cost. The annual maintenance cost is estimated to be 1% investment cost of hydropower plant [7]. This cost has been considered in the calculations of economic benefit in Table 4.

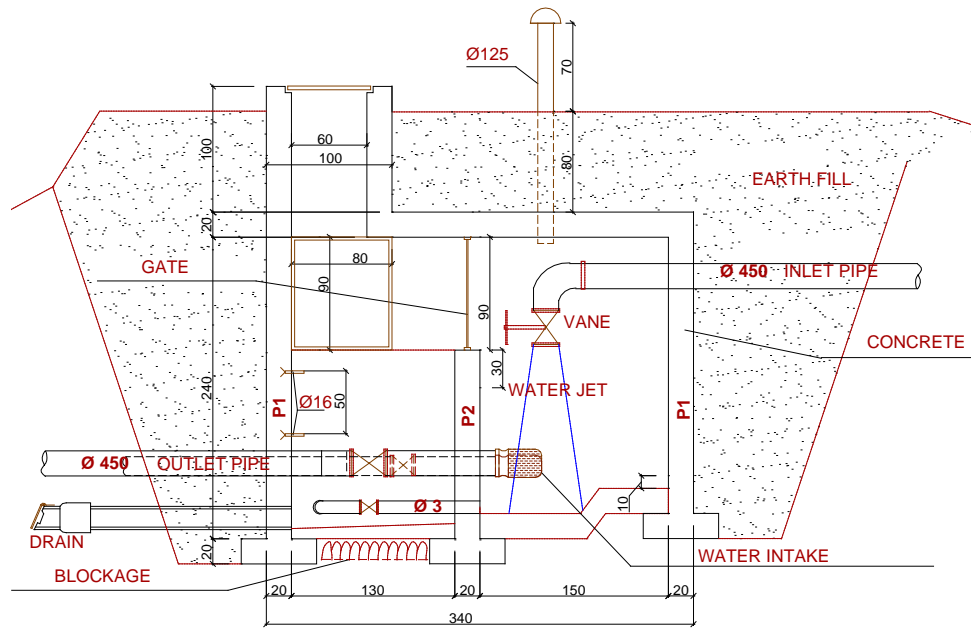


Fig.5 Longitudinal profile of the pressure reduction tank.

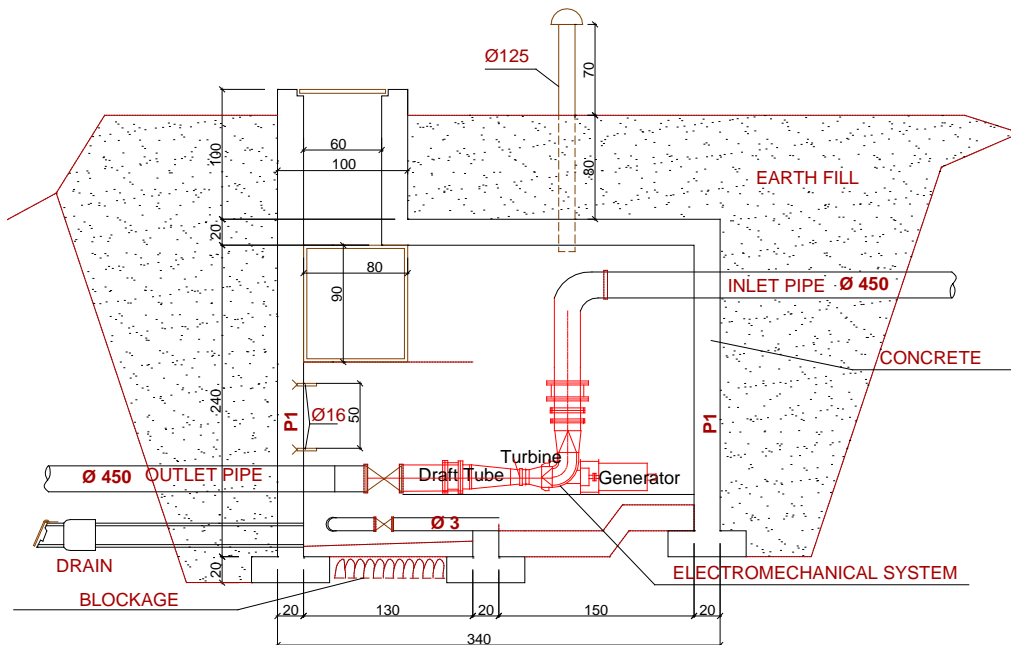


Fig.6 Hydropower generation in the pressure reduction tank.

The water supply system of Edremit has an electric energy potential of 4.08 GWh/year, corresponding to about 560,118 Euro/year economic benefit. The financing of the project would be supplied from international funding organizations like World Bank and European Union.

Table 4. Economic Analysis of The Proposed Project

Total Installed Capacity (kW)	559
The hours in operation (h/year)	7300
Annual Energy (kWh/year)	4,080,700
Cost of the investment (EUR)	1,118,000
Annual Benefit (EUR)	560,118
Payback period (year)	2.00

4. Conclusions

Utilization of the existing hydropower potential in water supply networks has been analyzed. The proposed facility has numerous advantages compared to river-type hydropower plants. The new energy laws and the economic aspects of Turkey create opportunity to develop this potential. For a case study, the water supply system of Edremit has been investigated in a detailed manner. There are 12 pressure reduction tanks along the water supply line and they have an power capacity of 559 kW. The proposed project is ecologically sustainable and it will produce clean and feasible energy.

References

- [1] ESHA-European Small Hydropower Association, Energy Recovery in Existing Infrastructures with Small Hydropower Plants: Multipurpose Schemes-Overview and Examples, 2010.
- [2] Kucukali, S. and Baris, K., Assessment of small hydropower (SHP) development in Turkey: Laws, regulations and EU policy perspective, *Energy Policy*, 37, 2009, 3872-3879.
- [3] Kucukali, S., Municipal water supply dams as a source of small hydropower in Turkey, *Renewable Energy*, 35(9), 2010, 2001-2007.
- [4] Bank of Provinces, Regulation on the Preparation of Water Supply Projects for Cities and Towns, 1992.
- [5] Turkstat, Turkish Statistical Institute, 2009. (www.turkstat.gov.tr).
- [6] DSI- General Directorate of State Hydraulic Works, Dams and hydroelectric power plants in Turkey. DSI, Ankara, 2005.
- [7] Linsley, R.K., Franzini, J.B., Freyberg, D.L., Water Resources Engineering. McGraw-Hill Publications, 1992.