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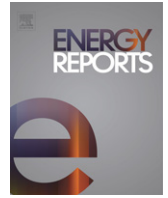
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Water management for sustainable and clean energy in Turkey



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ABSTRACT

Water management has recently become a major concern for many countries. During the last century consumption of water and energy has been increased in the world. This trend is anticipated to continue in the decades to come. One of the greatest reasons is the unplanned industrial activities deteriorating environment in the name of rising standard of life. What is needed is the avoidance of environmental pollution and maintenance of natural balance, in the context of sustainable development. However, Turkey's geographical location has several advantages for extensive use of most of the renewable energy resources. There is a large variation in annual precipitation, evaporation and surface run-off parameters, in Turkey. Precipitation is not evenly distributed in time and space throughout the country. There are 25 hydrological basins in Turkey. But the rivers often have irregular regimes. In this situation the main aim is to manage and use the water resources for renewable, sustainable and clean energy. This paper deals with water management for renewable, sustainable and clean energy in Turkey.

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1. Introduction

Water issues are multi-dimensional including economical, social, political and cultural aspects. The United Nations Millennium Declaration adopted the goal of reducing by half the proportion of people without access to safe drinking water by the 2015. An additional goal was set at the World Summit on Sustainable Development in Johannesburg to reduce by half the proportion of people without access to basic sanitation by 2015 (DSI, 2009).

As Turkey is a developing country, the water resources must be developed in an efficient way which optimizes benefits of water – more crop per drop –, while minimizing negative environmental impacts (DSI, 2009).

The availability of water per capita per year in Turkey is only about one fifth of that of the water rich countries. It is therefore imperative that Turkey should improve per capita water availability in order to enhance the quality of life of her people. Therefore, in recent decades, Turkey has made great success in water resources development for domestic use, irrigation, power generation, flood control, and other purposes (DSI, 2009).

Water resources management around the world has taken many different forms and directions since the dawn of civilization. Humans have long sought ways of capturing, storing, cleaning, and redirecting freshwater resources in efforts to reduce their

vulnerability to irregular river flows and unpredictable rainfall. Early agricultural civilizations were formed in regions where rainfall and runoff could be easily and reliably tapped. The first irrigation canals permitted farmers to grow crops in drier and drier regions and permitted longer growing seasons. The growth of cities required advances in the science of civil engineering and hydrology as water supplies had to be brought from increasingly distant sources (Yuksel, 2012; Gleick, 2000; Kaygusuz, 2002).

Comprehensive water planning activities have been carried out in Turkey since the 1950s. These have led to the construction of structures on rivers to regulate the flow and to meet the energy and food requirements of a growing population while achieving socio-economic development goals (DSI, 2009).

Turkey's water management policies are directed towards satisfying the increasing demand for domestic water supply, achieving food security, generation of energy, and conserving the environment in accordance with international standards (DSI, 2009).

2. Water resources in Turkey

However, Turkey's geographical location has several advantages for extensive use of most of the renewable energy resources. There is a large variation in annual precipitation, evaporation and surface run-off parameters, in Turkey. Precipitation is not evenly distributed in time and space throughout the country. There are 25 hydrological basins in Turkey. But the rivers often have irregular regimes. The 25 hydrological basins in Turkey have a total surface

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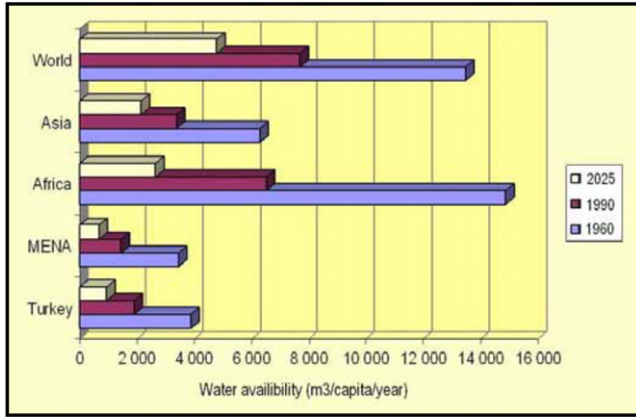


Fig. 1. Water availability in the world. Source: Ref. (DSI, 2009).

water run-off of 193 billion m³/year. 31% of the potential is constituted by the Euphrates (Firat) and the Tigris (Dicle) Rivers both of which have their sources in the eastern part of the country.

Taking into consideration the population of 2014 which is 77 million, the quantity of water per capita per year is 1.586 m³. Countries regarded as being rich in water resources have 8–10 thousand m³ water per capita per year. The available water per capita per year in Turkey is about 1/5 of the water-rich countries. It should be noted that Turkey, contrary to the prevailing belief, is not a water-rich country. Furthermore Turkey is not the richest country of the region in terms of water resources (Fig. 1). The available water per capita in Turkey is less than the world average. Furthermore, it is estimated by the experts that, in 2023, the amount of available water will likely to be less than 1000 m³/capita/year.

Water resources are allocated to the various sectors by the DSI in line with an integrated water resources management approach. Fig. 2 shows water potential and consumption by basins for 2008.

Turkey gives great importance to integrated regional development projects. The Southeastern Anatolia Project (GAP), Eastern

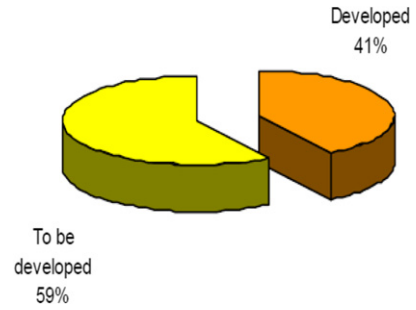


Fig. 3. Development of water potential. Source: Ref. (DSI, 2009).

Anatolia Project (DAP) and Konya Plain Project (KOP) can be mentioned among them. As shown in Fig. 3, only 41% of total exploitable water potential of the country has been consumed until now. It is planned that remaining part would be developed by 2023 which is the 100th Anniversary of Turkish Republic.

3. Water management for development of water potential in Turkey

Turkish Electricity Transmission Company (TEIAS), has prepared the Long-Term Energy Generation Plan, taking into consideration the MAED model (Yuksel, 2012; MENR, 2005), demand outcome. According to the Plan, the installed capacity will increase to 57,551 MW in 2010 and to 117,240 MW in 2020. The installed hydropower capacity is anticipated to increase to 18,943 MW in 2010 and to 34,092 MW in 2020. Thus, an additional 1000 MW of hydro capacity should be added to the system annually over the next 20 years. Turkey is thus seeking support for the development of all its economic potential by 2023, which is the 100th anniversary of the foundation of the Turkish Republic (Yuksel, 2012; IHA, 0000; TEIAS, 2005; Yuksek et al., 2006; Kaygusuz, 2009).

The water potential of countries is usually evaluated based on water potential per capita. According to international criteria, countries with a water potential greater than 10,000 m³ per capita

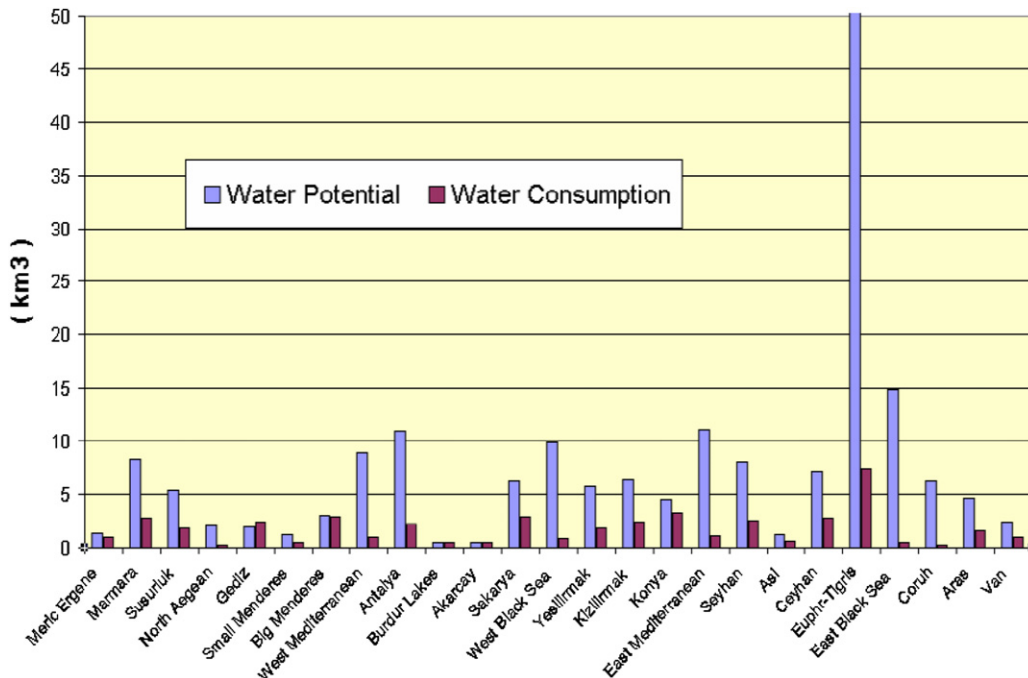


Fig. 2. Water potential and consumption by basins in Turkey. Source: Ref. (DSI, 2009).

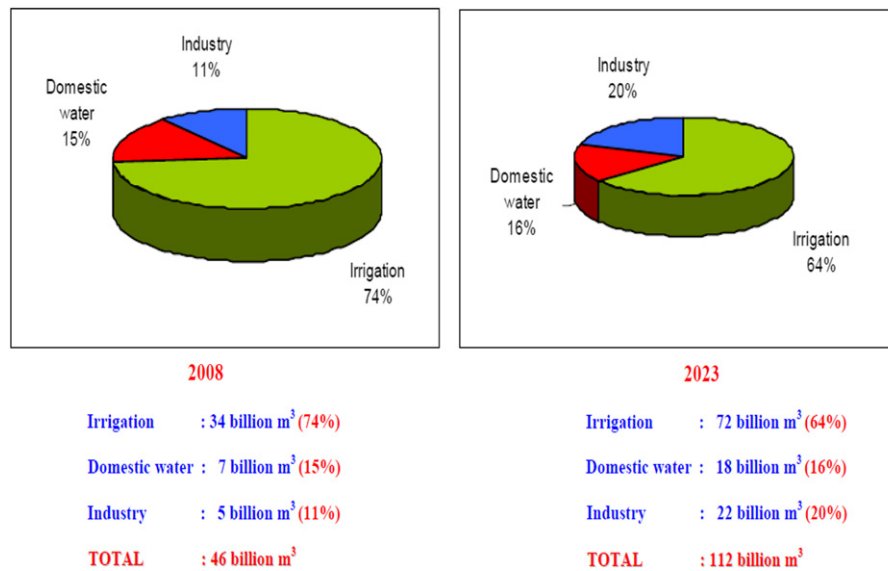


Fig. 4. Water consumption projection in Turkey.
Source: Ref. (DSI, 2009).

per year are accepted as water-rich; countries with a potential of 3000 to 10,000 m³ are accepted as self-sufficient; countries with a potential of 1000 to 3000 m³ are accepted as having a water-deficit; and, those with a water potential of less than 1000 m³ per capita per year are regarded as water-poor countries (Yüksel, 2008b; DSI, 2004).

In Turkey, while the gross water potential per capita was 3700 m³ at the beginning of 1997, this fell to 3000 m³ at the beginning of 2000 and it is estimated to decrease to 2000 m³ in 2010 as a result of the population increase. However, when evaluated on the basis of the average annual exploitable potential, this figure will be about 1300 m³. Thus, as understood from these figures, some regions of the country will face water scarcity in drought seasons and Turkey will become a water-deficit country in the future (Yüksel, 2008b; DSI, 2004; DIE, 2004). In various sectors, as 34 billion m³ in irrigation, 7 billion m³ in domestic water supply and 5 billion m³ in industry totally 46 billion m³ of water was consumed in 2008. This sum corresponds to only 41% of the available exploitable potential of 112 billion m³.

According to future projections, the share of irrigation use will decrease from 74% in 2008 to 64% by 2023 (Fig. 4). On the other hand, the domestic and industrial use would increase to 16% and 20% in this period, respectively (DSI, 2009).

The water requirement increases steadily and the agricultural sector is the major consumer of water in Turkey with about 34 billion m³/year while the water volume to be utilized by this sector would be expected at the level of 72 billion m³/year by 2023. Regarding groundwater, exploitable groundwater resources of Turkey are 13,66 billion m³/year excluding the discharge of springs feeding surface water resources.

At present, 90% (12,42 billion m³/year) of the groundwater reserve has been allocated, 55% (6,77 billion m³/year) of which is for irrigation (including private use of 2,74 billion m³/year) and 45% (5,65 billion m³/year) is for domestic and industrial purposes (DSI, 2009).

4. Water utilization and hydropower for renewable and clean energy in Turkey

Renewable energy supply in Turkey is dominated by hydropower and biomass (Yüksek et al., 2006; MENR, 0000; DPT, 2006; MEF, 2007; TEIAS, 2009; EIE, 2009; Kaygusuz and Kaygusuz,

2002; Kaygusuz, 2010), but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. Total renewable energy supply declined from 1990 to 2007, due to a decrease in biomass supply (Yüksel and Kaygusuz, 2011; IEA, 2009). As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources. Table 1 shows potentials for investment for renewable energies in Turkey (MENR, 0000; EIE, 2009; Yüksel and Kaygusuz, 2011; IEA, 2009; Celiktas and Gocar, 2009).

Hydropower is a renewable form of energy since it uses the power of flowing water, without vested or depleting it in the generation of energy. Because they are clean energy generation plants hydropower can contribute to reducing air pollution and slowing down global warming. Any other air pollutants or toxic wastes are not produced and it promotes energy safety independence and price stability. Hydropower is an electricity source with long viability and low operation and maintenance cost (DSI, 2009; Kaygusuz, 2009; Yüksel, 2008b; Yüksel and Kaygusuz, 2011; IEA, 2009; Celiktas and Gocar, 2009; Yüksel, 2009).

4.1. Hydropower in Turkey

Dams that produce electricity by this most productive renewable clean energy source in the world provide an important contribution to the reduction of air pollution. The result of an investigation held in the USA suggests that the productivity of hydroelectric power-plants is higher than 90% of thermal plants and this figure is twice that of thermal plants. Because of irregular hydrological conditions and rapid sedimentation of reservoirs, some people have claimed that hydro plants do not produce as much energy as planned. But this is wrong information. It is also claimed that the cost of the removal of dams entirely filled by sediment at the end of their physical lives is not considered in the total project cost, and that there are major problems in recovering the cost of investment and environmental issues (UNDP, 2000; Yüksel and Sandalci, 2011).

Turkey has important hydropower potential. Therefore, Turkey has rigorous plans for the development of its substantial hydropower potential. Approximately 5500 MW of hydropower capacity is under construction, the largest schemes being Deriner

Table 1

Potentials for investment for renewable energies in Turkey.

Source: Refs. (MENR, 0000; Yüksel and Kaygusuz, 2011; Celiktas and Gocar, 2009).

Sectors	Million €	Remarks
Hydroelectric	114	Economical development potential of 28,600 MW, corresponding 100,000 GWh/a
Wind power	57	Economical development potential of 48,000 MW with wind speed >7 m/s
Solar thermal	165	Economical development potential of 131,000 GWh/a, corresponding to approx. 300 million m ² collector area
Biogas	4	Agricultural residual material and dung, when used for electricity generation, 1000 MWe and 7000 GWh/a
Total	340	

Table 2

Development of irrigation, hydropower and water supply in Turkey.

Source: Refs. (Yüksel, 2012; DSI, 2006).

	In operation (2005)	Ultimate goals (2030)	Development rates (%)
Irrigation	4.9 million ha	8.5 million ha	58
Hydroelectric energy	45.3 billion kWh	127.3 billion kWh	36
Water supply	10.5 billion m ³	38.5 billion m ³	27

Dam in the north of the country (680 MW) and Berke Dam in the southeast (520 MW). Schemes built on the concept of build operate transfer (BOT) are being encouraged strongly, and bilateral agreements have been signed with a number of countries to further international cooperation in hydropower development. In Turkey, 566 hydropower projects by DSI have been identified for development in total, 130 are already in operation, 31 are under construction, and 405 (with a capacity of 19 951 MW) are planned (Table 2), Yüksel (2012), Yüksel (2009), EIA (2006), IEA (2006), DSI (2006), EIE (2006), Yüksel (2010b), Yüksel (2008a), and Yüksel (2010a).

In view of the considerable variation in run-off in terms of seasons, years and regions, it is absolutely necessary for the major rivers in Turkey to have water storage facilities, to allow for 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 throughout the 48 years that have elapsed since the establishment of the State Hydraulic Works (DSI) (Yüksel, 2010b; Kaygusuz, 2004).

Rivers weave in and out of our lives, providing innumerable benefits to communities across the world. In our planet, the rivers for drinking water, irrigation, aquatic habitat, fisheries, energy, navigation, recreation and simply the natural beauty they bring to our landscapes. Humans have been building dams and other water constructions for irrigation, electricity, water supply, etc. All these are benefit for humans' life. On the other hand, by design, dams alter the natural flow regime, and with it virtually every aspect of a river ecosystem, including water quality, sediment transport and deposition, fish migrations and reproduction, and riparian and floodplain habitat and the organisms that rely on this habitat. Dams also require ongoing maintenance. For example, reservoirs in sediment-laden streams lose storage capacity as silt accumulates in the reservoir. In arid climates reservoirs also experience a high rate of water loss to evaporation (Yüksel, 2010b; AR, 2004).

The Southeastern Anatolia Project (GAP) project originally planned by the State Hydraulic Works is a combination of 12 major projects primarily for irrigation and hydroelectric generation. The project includes the construction of 22 dams and 19 hydroelectric power plants on the Euphrates and the Tigris rivers and their tributaries. It is planned that upon completion, over 1.8 million ha of land will be irrigated and 27 billion kWh hydroelectric energy will be generated annually.

The GAP area is rich in water resources. The Euphrates and Tigris rivers represent over 28% of the country's water supply by rivers, and the economically irrigable areas in the region make up 20% of those for the whole Turkey. The development of the region was originally planned as relating to its water resources, which

were later combined in a comprehensive water and land resources development package (DSI, 2004; Yüksel, 2010b, 2006).

The package included the construction of 22 dams, 19 hydroelectric power plants and the irrigation facilities to serve 1.7 million ha of land. The total installed capacity of the power plants is 7500 MW with an annual production of over 27 billion kWh. There are two main basin projects: the Euphrates and the Tigris basin projects. The Euphrates basin projects has 5304 MW installed capacity, will generate 20 billion kWh of energy and will irrigate 1 million ha of land. 14 dams and 11 hydroelectric power plants are planned for this basin. The Tigris basin projects have 2172 MW installed capacity, will generate 7 billion kWh of electric energy and will irrigate 700 000 ha of land area. Eight dams and eight hydroelectric power plants are planned for this basin (Yüksel, 2010b; Unver and Gupta, 2003).

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 geographically vary greatly (Yüksel, 2012; DSI, 2004; DIE, 2004). 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 (Yüksel, 2012; DIE, 2004).

With the projects developed primarily by DSI and other institutions engaged in water resources development, water consumption in Turkey reached 39.3 billion m³ by 2000, corresponding to only 36% of the economically exploitable water resources. During water consumption estimates on a sectoral basis, it is accepted that all of the economically irrigable land will be irrigated with irrigation schemes constructed by the year 2030 and water consumption for irrigation will be 71.5 billion m³. Hence, while its share in the total consumption was 75% in 1999, the share of irrigation water in the total water consumption will be decreased to 65% by the year 2030, through the utilization of modern irrigation techniques (Table 3) (Yüksel, 2012; MENR, 2005; Yüksel, 2008b).

5. Conclusion

Water and energy are the two important engines of sustainable development. In the energy sector, the basic policy of Turkey is the provision of cheap electrical energy on time and in sufficient quality and quantity. Investments in hydropower deserve special support as they are clean and have a long economic life-span.

To conclude, the development of water resources constitutes an important element in Turkey's economic development programme. There are several outstanding challenges which constitute the basis for future action. All of these need to be overcome by

Table 3

Distribution of the hydropower potential in Turkey by project implementation status.

Source: Refs. (Yüksel, 2012; DSI, 2006).

Status	Number of project	Installed capacity (MW)	Total annual power generation capacity			
			Firm (GWh)	Mean (GWh)	Cumulative (GWh)	Mean (%)
In operation	130	12251	32 984	44 388	44 034	35.0
Under construction	31	3338	6 467	10 845	55 233	9.0
Final design completed	19	3570	7 029	10 897	66 130	9.0
Under final design operation	21	1333	2 492	4 494	70 624	4.0
Planned	119	6091	10 861	22 324	92 948	18.0
Under planning	57	1978	4 214	7 602	100 550	6.0
Master plan completed	40	2691	5 674	9 195	109 745	7.0
Reconnaissance completed	107	3920	8 523	15 184	124 929	12.0
Initial study completed	42	368	526	1 180	126 109	1.0
Total potential	566	35 540	78 770	125 129		100.0

developing this precious resource in an equitable, reasonable and optimal way. Therefore, it is of considerable importance for Turkey that the development, management, use and protection of water resources should be planned in an integrated manner taking into account all the economic and social needs of its people.

It is important to point out the restructuring policies that are directing the development of new and renewable energy, and giving special emphasis to socio-economical bodies, laws and legal regulations. In this respect, particular attention and priority should be given to the development of the hydroelectric potential in Turkey, since it is the most important natural renewable resource and only 35% of the technically and economically utilizable hydro potential has been developed so far.

Since there is a strong relationship between sustainable water management and economic development, it is of prime importance to ensure investment in the water sector while taking environmental concerns into account. In order to overcome the financial barriers to investment, private enterprises, both local and foreign, have been encouraged through the BOT model.

On the other hand, hydro plants are minimal compared with alternative resources. They make use of our renewable “green energy” resource, without causing pollution and CO₂ emission. They have considerable advantages, since they use the renewable sources of the country, are free of fuel costs, and their design and construction can be performed by Turkish engineers and contractors. They are also easily adaptable to the system load demands.

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