THE IMPORTANCE OF HYDROPOWER PLANTS IN TURKEY'S ENERGY PLANNING

Ömer YÜKSEK
yuksek@ktu.edu.tr

Murat KANKAL
mkankal@ktu.edu.tr

Murat İhsan KÖMÜRCÜ
mkomurcu@ktu.edu.tr

Hızır ÖNSOY
honsoy@ktu.edu.tr

Adem AKPINAR
aakpinar@ktu.edu.tr

Karadeniz Technical University Civil Engineering Department, Trabzon, Turkey
Tel : (+90) 0 462 377 26 41, 0 462 377 26 33, Fax: 0 462 325 66 82

Mustafa Haluk FİLİZ
General Directorate of State Hydraulic Works (DSİ), 22. Division, Trabzon, Turkey
Tel : (+90) 0 462 334 11 05 mhalukfiliz@dsi.gov.tr

ABSTACT

Energy is considered to be one of the key factors in economical development. Sustainable energy resources are of vital importance and the energy resources, which are continuously available for long durations and which have no detrimental social effects, are compulsory for sustainable development. The fact that fossil originated energy resources are both exhaustible and have detrimental effects to environment has made inevitable to focus on alternative resources. The alternative energy resources, including hydropower, have some important advantages, such as being sustainable, renewable, environmentally friendly and clean resources. The inherent technical, economic and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix, particularly in the developing countries. This paper deals with the importance of hydropower plants to meet the increasing electricity demand for Turkey. Hydropower is emphasized as Turkey's renewable energy sources. Turkey's small hydro power potential is found to be an important energy source. The results of a study in which Turkey's long term demand up to 2020 has been predicted are also presented. According to the results, Turkey's

hydro electric potential can meet 33 to 46 % of its electric energy demand in 2020 and this potential may easily and economically be developed.

Key Words: Energy Resources and Planning, Turkey's Energy Demand, Hydro Power.

1. INTRODUCTION

Energy is considered to be a key player in the generation of wealth and also a significant component in economic development. This makes energy resources extremely significant for energy country in the world. In bringing energy needs and availability into balance, there are two main elements such as energy demand and energy supply. In this regard, every country should put efforts to attain such a balance and hence conduct research and development studies to develop its own energy conservation programs for the existing and new energy resources. In conjunction with this, there is an ongoing action for energy market reform in International Energy Agency (IEA) countries. So, energy market reform in 1998-99 focused primarily on the electricity sector and to a lesser extent on gas. Reform in both sectors offers strong potential gains in efficiency through the unbundling of production, transmission and distribution [Dincer 2002].

Sustainable development demands a sustainable supply of energy sources. One of the most important implications of this statement is as follows (Dincer, 2003): Sustainable development in a society requires a supply of energy sources that, in a long term, is readily and sustainably available at reasonable cost and can be utilized for all required tasks without causing negative social effects. Supplies of such energy resources as fossil fuels are finite; other energy sources, including hydro power, are generally considered renewable and therefore sustainable over the relatively long term [Yuksek et al., 2006].

Renewable energy technologies have made significant progress during the last few decades and contribute significantly to the energy mix of many countries around the world. Confidence is growing that the world is beginning the transition to a more sustainable energy system in which renewable resources will play an expanding role. On the other hand, renewables could make a substantial contribution to national economic and environmental objectives. They can do this by mitigating security risk, enhancing effectiveness of energy systems, achieving environmental goals and providing energy services in locations where other resources are not available [Kaygusuz et al., 2006].

In 2004, a comprehensive study was carried out by various official organizations to predict the long term electric energy demand. The results of this study were published by a report entitled "Report of Turkey Long Term Electric Energy Demand" [RTLED, 2004]. Various development and consumption scenarios were applied in the study.

In this paper, the results of the aforementioned study are presented and the hydro electric power potential in meeting the demand is studied. By taking into account the predictions of long term energy demand; the main objectives of this study are; to evaluate quantitatively Turkey's hydro power capacity and, to emphasize the importance of hydro power as a cost effective and environmentally friend energy resource.

2. PREDICTION OF LONG TERM ELECTRIC ENERGY DEMAND

A demand prediction model, called "Model for Assessment of Energy Demand" (MAED) was used to predict Turkey's long term electric energy demand. This model, prepared by International Atom Energy Agency (IAEA), is a simulation model which evaluate mid and long term energy demands. The input list of the model comprises various technical and political parameters; such as variation in the social needs of the people, development and industrialization policy of the country and improvement in transportation and technology, etc. The total energy demand is given as demand in agriculture, industry, transportation, housing and services. MAED evaluates future energy needs based on mediumto long term scenarios of socioeconomic, technological and demographic development in a country or region.

The electric energy demand varies according to various parameters. The main parameters to affect the energy demand are: Gross National Product (GNP); population and demographic variations; development in housing, industry, agriculture and transportation sectors; income per capita; climatic conditions; employment, technological development, etc.

Three kinds of scenario were applied in the model: Scenario 1 depends on the Gross National Product (GNP) values of State Planning Organization (DPT) in 8 May 2002. GNP values were modified by DPT in 30 April 2004 and Scenario 2 depends on the modified GNP values. Scenario 3 depends on production industry prediction values different from Scenario 2. The other parameters are the same of Scenario 2. The details of the scenarios and execution of the model in Turkey may be found in "Report of Turkey Long Term Electric Energy Demand" [RTLED, 2004].

MAED Model was executed for the above three scenarios and Turkey's annual electric energy demand values were predicted from 2004 to 2020. The results are given in Table 1. Annual increase ratios are also given in Table 1. As can be seen, annual average increase ratio values are 8.66 %, 7.76 % and 6.38 % for the Scenarios 1, 2, and 3, respectively.

Table 1. Turkey's annual electric energy demand values

Year	Scenario 1		Scenario 2		Scenario 3	
	Increase (%)	Demand (GWh)	Increase (%)	Demand (GWh)	Increase (%)	Demand (GWh)
2005	11.4	168262	8.0	163191	5.5	159399
2006	10.3	185600	8.1	176400	6.3	169520
2007	10.0	204150	8.1	190700	6.3	180250
2008	9.9	224300	8.2	206400	6.3	191680
2009	9.7	246150	8.3	223500	6.3	203830
2010	9.6	269842	8.3	242021	6.3	216750
2011	9.6	295800	8.3	262000	6.3	230400
2012	9.3	323200	8.2	283500	6.3	244950
2013	8.7	351300	8.0	306100	6.3	260400
2014	8.2	380000	7.9	330300	6.3	276800
2015	7.8	409531	7.8	356202	6.4	294563
2016	7.2	439100	7.5	383000	6.5	313600
2017	7.1	470175	7.2	410700	6.6	334300
2018	6.8	501950	7.0	439600	6.6	356500
2019	6.7	535425	6.8	469500	6.7	380500
2020	6.6	570521	6.4	499489	6.8	406530

3. TURKEY'S HYDROELECTRIC POWER POTENTIAL

3.1. A GENERAL VIEW TO TURKEY'S ENERGY STATUS

Because of social and economic development of the country, the demand for energy and particularly for electricity is growing rapidly in Turkey. The main indigenous energy resources are hydro, mainly in the eastern part of the country, and lignite. Turkey has no big oil and gas reserves. Almost all oil natural gas (NG) and high quality coal are imported. It has a large potential for renewable energies. In Turkey, where there is no nuclear power, electricity is produced by thermal power plants (TPPs), consuming coal, lignite, NG, fuel oil and geothermal energy; and by hydro power plants (HPPs) [Yuksek et al, 2006].

Turkey's geographic location has several advantages for extensive use of most of the renewable energy sources. It is on the humid and warm climatic belt, which includes most of Europe, the near East and western Asia. As a developing country, Turkey's population is estimated to be over 100 million by 2020 [DIE, 2004]. Demographic projections as well as the growing gap between national energy demand and production raised concerns on the economical and environmental impacts of power generation based on Turkey's national energy sources.

Meeting energy demand is of high importance in Turkey. But exploiting the country's large energy efficiency potential is also vital. Air pollution is a significant problem and, as the government's projections show, carbon emissions could rise sharply if current trends continue [Kaygusuz, 2002b]. Turkey is striving to make good use of its geographic location as a transit country linking the oil- and gas-rich Caspian area to the Mediterranean and to the demand centers of the West. Several pipeline projects are under way. They could have a positive effect on the diversity and security of supply in many consuming countries. They could also help avoid further environmental strain on the maritime routes through the Bosporus. Several of these pipelines, including the Baku-Tbilisi-Ceyhan crude oil pipeline and the “Blue Stream” gas pipeline under the Black Sea, are gradually nearing completion, but some additional attention to committing resources to these lines may be warranted [Kaygusuz, 2001; MENR, 2004].

Hydropower energy and the surrounding seas are Turkey’s main potential sources of renewable energies. The other major areas of renewable energy research in Turkey are, solar thermal, wind, geothermal, photovoltaic energy, and new programs such as hydrogen energy, fuel cells, etc. [Kaygusuz, 2002a].

3.2. HYDROELECTRIC POWER IN THE WORLD AND IN TURKEY

Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, or other machinery. The power available is proportional to the product of pressure head and water discharge. Hydropower is the largest renewable resource used for electricity [Frey and Linke, 2002]. It plays an essential role in many regions of the world with more than 150 countries generating hydroelectric power. A survey in 1997 by The International Journal on Hydropower & Dams found that hydro supplies at least 50 % of national electricity production in 63 countries and at least 90 % in 23 countries. About 10 countries obtain essentially all their commercial electricity from hydro, including Norway, several African nations, Bhutan and Paraguay. There is vast unexploited potential worldwide for new hydro plants, particularly in the developing countries of Asia, Latin America and Africa, while most of the best sites have already been developed in Europe and North America. There is also upgrading potential at existing schemes though any future hydro projects will, in general, have to satisfy stricter requirements both environmentally and economically than they have in the past [Bartle, 2002].

It is expected that the world energy demand, and especially that for electricity, will increase greatly during the 21st century, not only because of demographic pressures, but also through an improvement in living standards in the less developed countries, which will represent 7 billion inhabitants in 2050 (78 % of the total) [IEA, 2001]. Consumption of primary energy will increase up to threefold by the middle of this century, and the increase will be even greater for electricity. In view of this situation, many sources of energy will be necessary, but for environmental reasons, a high priority should be the development of all technically feasible potential from clean renewable sources, especially hydropower.

Theoretical, technically feasible, and economically feasible hydro electric potential by region in the world as well as in Turkey is presented Table 2 [Herzog et al., 2004]. As shown in this table, the world's gross theoretical hydropower potential is about 40000 TWh/year, of which about 14000 TWh/year is technically feasible for development and about 7000 TWh/year is currently economically feasible. The biggest growth in hydro generation is expected in the developing countries where there is still a large potential for hydro development, while relatively little growth is expected in most OECD countries where more than 65 % of the economic potential is already in use [Koch, 2002; IEA, 2002].

Table 2. Theoretical, technically and economically feasible hydro electric potential by region

Region	Gross Theoretical Potential (TWh/year)	Technically Feasible Potential (TWh/year)	Economically Feasible Potential (TWh/year)	Installed Hydro Capacity (GW)	Hydro Power Production (TWh/year)
North America	5817	1509	912	141.2	697
Latin America and Caribbean	7533	2868	1199	114.1	519
Western Europe	3294	1822	809	16.3	48
Central and Eastern Europe	195	216	128	9.1	27
Former Soviet Union	3258	1235	770	146.6	498
Middle East and North Africa	304	171	128	21.3	66
Sub-Saharan Africa	3583	1992	1288	65.7	225
Centrally Planned Asia	6511	2159	1302	64.3	226
South Asia	3635	948	103	28.5	105
Pacific Asia	5520	814	142	13.5	41
Pacific OECD	1134	211	184	34.2	129
WORLD TOTAL	40784	13945	6965	654.8	2581
TURKEY	435	215	128	12.6	45
Turkey/World Total (%)	1.07	1.54	1.84	1.92	1.74

Hydropower continues to be the most efficient way to generate electricity. Modern hydro turbines can convert as much as 90 % of the available energy into electricity. The best fossil fuel plants are only about 50 % efficient. Hydro resources are also widely distributed compared with fossil and nuclear fuels and can help provide energy independence for countries without fossil fuel resources. Hydropower is a significant source of electricity worldwide and will likely continue to grow especially in the developing countries [Kaygusuz, 2004]. While large dams have become much riskier investment, there still remains much unexploited potential for small hydro projects around the world.

Since hydropower have various economical, environmental and social and strategic advantages, Turkey's hydropower potential will be discussed in the following sections. The annual average precipitation in Turkey is nearly 643 mm, corresponding to a volume of 500 km^3. The average runoff coefficient is 0.37, and the annual runoff is 186 km^3 (2400 m^3/ha). Subtracting from this figure the estimated water rights of neighboring countries, minimum stream flow requirements for pollution control, aquatic life and navigation, and topographic and geologic constraints; the annual consumable water potential of 12 km^3 should be added to this, bringing the total annual consumable potential to 107 km^3 [Yuksek and Ucuncu, 1999]. Turkey has rigorous plans for the development of its hydropower potential. Schemes built on the concept of build-own-transfer (BOT) are being encouraged strongly, and bilateral agreements have been signed with a number of countries to further international cooperation in hydropower development [Yuksek and Kaygusuz, 2006].

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 the small and large hydropower development in Turkey. For putting this aim into practice, some of small hydropower plants are still under construction [Yuksel, et al, 2005].

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. Those are being designed are divided into seven sub groups and are given in Figure 1 as follows [EIE, 2004]: 11 027 GWh/year (9 %) with final design ready, 4 243 GWh/year (3 %) with final design under preparation, 23 183 GWh/year (18 %) with feasibility report ready, 5 339 GWh/year (4 %) with feasibility report under preparation, 11 113 GWh/year (9 %) with master plan ready, 15 707 GWh/year (12 %) with preliminary report ready and 1 727 GWh/year (1 %) with preliminary report under preparation [Yuksek, et al, 2006].

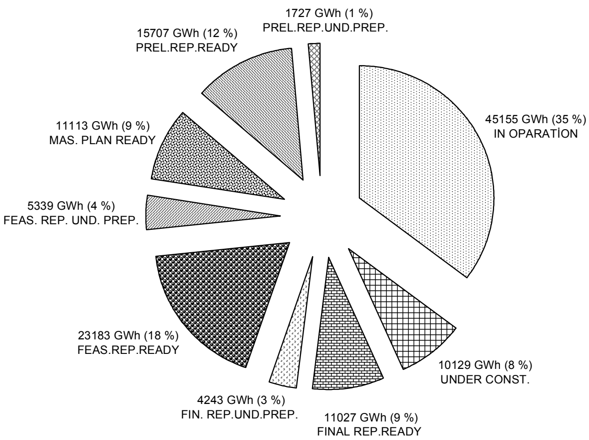

Fig. 1. Distribution of Turkey hydro power potential according to design level

According to findings of a study, which was carried out by Bakir [Bakir, 2005], in which a new criterion was developed related to key concept of "the economical feasibility", by taking into consideration some undervalued and even ignored benefits of hydro plants and some overvalued benefits of thermal power plants; economically feasible hydropower potential goes up 188 TWh/year, with an increase ratio of 47 % compared to DSI value. Turkey's hydropower potential according to DSI and the new developed criteria together with installed power values are given in Table 3.

Table 3. Turkey's annual hydropower potential according to DSI and new criteria

Basin	Gross Pot. (GWh)	Potential According to DSI		Potential Acc. to New Criteria	
		Econ. Feasib. Pot. (GWh)	Installed Power (MW)	Econ. Feasib. Pot. (GWh)	Installed Power (MW)
Firat (Euphrates)	84 122	39 375	10 345	46 267	12 176
Dicle (Tigris)	48 706	17 375	5 416	24 353	7 610
Eastern Black Sea	48 478	11 474	3 257	24 239	6 925
Eastern Meditt.	27 445	5 216	1 490	10 978	3 137
Antalya	23 079	5 355	1 537	9 232	2 638
Coruh	22 601	10 933	3 361	12 431	3 825
Ceyhan	22 163	4 825	1 515	8 865	2 860
Seyhan	20 875	7 853	2 146	9 394	2 609
Kizilirmak	19 552	6 555	2 245	7 821	2 697
Yesilirmak	18 685	5 494	1 350	8 408	2 213
Western Black Sea	17 914	2 257	669	7 166	2 108
Western Meditt.	13 595	2 628	723	5 438	1 511
Aras	13 114	2 372	631	5 246	1 418
Sakarya	11 335	2 461	1 175	3 967	1 984
Susurluk	10 573	1 662	544	2 643	881
Others (Total)	30 744	1 788	546	1 721	507
Total	432 981	127 623	36 950	188 169	55 099

Taking into consideration the electric energy demand predictions (given in section 2 and in Table 1) and the hydropower potential according to the new criteria (Table 3), it is obvious that, Turkey's hydropower potential can meet nearly 33 %, 38 % and 46 % of its electric energy demand in 2020, according to Scenarios 1, 2, and 3, respectively. Therefore, the hydro power potential is a very important resource in meeting its demand for Turkey, which has to strongly depend on foreign energy sources. Moreover, in preparing the hydro power potential, many of small hydro power plants are not taken into consideration. By evaluating these resources, of which potential may be in the order of some tens of TWh/year, it is not difficult to claim that Turkey will provide important part of its electric energy demand from its own hydro power resources.

3.3. SMALL HYDRO POWER

The development of hydro-electricity in the 20th century was usually associated with the building of large dams. Hundreds of massive barriers of concrete, rock and earth were placed across river valleys world-wide to create huge artificial lakes. While they created a major, reliable power supply, plus irrigation and flood control benefits, the dams necessarily flooded large areas of fertile land and displaced many thousands of local inhabitants. In many cases, rapid silting up of the dam has since reduced its productivity and lifetime. There are also numerous environmental problems that can result from such major interference with river flows [Paish, 2002]. Small, mini and micro hydro plants play a key role in many countries for rural electrification. Small-scale hydro is mainly 'run of river,' so does not involve the construction of large dams and reservoirs.

SHP is the main prospect for future hydro developments in Europe, where the large-scale opportunities have either been exploited already, or would now be considered environmentally unacceptable. Small hydro technology is extremely robust, also has the capacity to make a more immediate impact on the replacement of fossil fuels since, unlike other sources of renewable energy, it can generally produce some electricity on demand (at least at times of the year when an adequate flow of water is available) with no need for storage or backup systems. It is also in many cases cost competitive with fossil-fuel power stations, or for remote rural areas, diesel generated power [Kaygusuz, 2004].

To date, there is still no internationally agreed definition of 'small' hydro; the upper limit varies between 2.5 and 25 MW. In Turkey, the upper limit is accepted as 50 MW. The distribution of the hydro power plants, which are under design level, is presented in Table 4 according to their hydro capacity (EIE, 2004). 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 [Punys, 2004]. Being generally a mountainous country with annual average precipitation 643 mm, corresponding to a volume of 500 km^3, 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 [EIE, 2004].

Table 4. 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

4. RESULTS AND DISCUSSION

In this paper, the importance of hydropower plants to meet the increasing electricity demand for Turkey is researched. Firstly, the results of a study, which has been carried out to predict the Turkey's long term electric energy demand, are presented and then Turkey's hydro electric capacity and its importance in energy planning are studied.

Because of social and economic development of the country, the demand for energy and particularly for electricity is growing rapidly in Turkey. Depending on the applied scenario, Turkey's annual electric energy demand in 2010, 2015 and 2020 varies between 217 to 270 TWh, 294 to 410 TWh and 407 to 571 TWh, respectively.

From the viewpoint of energy sources such as petroleum and natural gas reserves, Turkey is not a rich country, but has an abundant hydropower potential to be used for generation of electricity. Turkey must base its energy strategy on developing the whole hydroelectric potential as soon as possible. Turkey's main indigenous energy resources are hydro and almost all oil natural gas and high quality coal are imported. Therefore, in order to avoid foreign dependency, Turkey must discover new and renewable energy resources. Renewable sources of power other than hydro (solar, wind, etc) are valuable options. But, even if major efforts were made to develop them, they will not be able to produce large amounts of energy in the coming decades. In assessing life cycle costs, hydropower consistently compares favorably with virtually all other forms of energy generation. Hydropower provides unique economical, environmental and social benefits, rarely found in other sources of energy development.

The net environmental benefits of hydropower are far superior to fossil-based generation. Turkey's annual total gross, technically feasible and economically feasible hydropower potentials calculated by DSI are 435, 215 and 128 TWh, respectively. However, according to findings of another study with a new criterion related to key concept of the economical feasibility, economically feasible hydropower potential goes up 188 TWh/year, with an increase ratio of 47 % compared to DSI value.

Taking into consideration the electric energy demand predictions and the hydropower potential according to the new criteria, it can be easily predicted that, Turkey's hydropower potential can meet nearly 33 %, 38 % and 46 % of its electric energy demand in 2020, according to Scenarios 1, 2, and 3, respectively. Moreover, in these calculations, many of small hydro power (SHP) plants are not taken into consideration. By evaluating these resources, of which potential may be in the order of some tens of TWh/year, it is obvious that, Turkey will provide important part of its electric energy demand from its own hydro power resources.

The hydropower industry is closely linked to both water management and renewable energy production, and so has a unique role to play in contributing to sustainable development in a world, where billions of people lack access to safe drinking water and adequate energy supplies. Globally, approximately 1.6 billion people have no access to electricity and about 1.1 billion are without adequate water supply. However, resources for hydropower development are widely spread around the world.

Potential exists in about 150 countries, and about 70 % of the economically feasible potential remains to be developed, mostly in developing countries, such as Turkey, where the needs are most urgent. Hydropower is a proven and well-advanced technology, with more than a century of experience. Modern power plants provide the most efficient energy conversion process (>90 %). The production of peak load energy from hydro allows for the best use to be made of base-load power from other less flexible electricity sources. As part of a multipurpose scheme, hydro can help to subsidize other important functions such as irrigation water supply, navigation improvements and recreation facilities.

5. CONCLUSIONS

The following concluding remarks may be drawn from this study:

Turkey's main indigenous energy resources are hydro and lignite and it has no big oil and gas reserves. Since almost all oil, natural gas and high quality coal are imported, Turkey has to discover new and renewable energy resources. Renewable sources of power other than hydro are valuable options. However, they do not seem to be able to produce large amounts of energy in the coming decades and hydropower consistently compares favorably with virtually all other forms of energy generation.

Turkey's annual total economically feasible hydropower potential calculated by DSI is 128 TWh. However, according to findings of another study, this figure goes up 188 TWh/year. Turkey's annual electric energy demand in 2010, 2015 and 2020 is predicted as goes up to 270 TWh, 410 TWh and 571 TWh, respectively. Hydropower potential can meet 33 to 46 % of its electric energy demand in 2020. By evaluating SHP plants, of which potential can be estimated to be in the order of some tens of TWh/year, Turkey will provide important part of its electric energy demand from its own hydro power resources.

By enlarging SHP potential, the economical status of the rural people, most of whom are unemployed and poor, will be improved by constructing various kinds of structures and thus by diminishing unemployment and by providing cheaper electricity for domestic usage. Therefore, the Turkish Government and policy makers should encourage and support hydropower and especially small hydropower.

REFERENCES

Bakir, N.N., Turkey's hydropower potential and review of electricity generation policies from EU perspective, 2005. http://www.ere.com.tr

Bartle, A., "Hydropower potential and development activities", 2002.. Energy Policy 30: 1231-1239.

DIE (State Statistics Institute), Statistics of Turkey in 2003, 2004, DIE, Turkey.

Dincer, I., "The role of exergy in energy policy making", 2002. Energy Policy 30, 137-149.

Dincer I., "On energy conservation policies and implementation practices", 2003. International Journal of Energy Research 27, 687-702.

EIE (Electrical Power Resources Survey and Development Administration), Hydro Electric Power Plant Projects Carried out by EIE, 2004, Ankara, Turkey, 1-45 (in Turkish).

Frey, G. W., Linke, D. J., "Hydropower as a renewable and sustainable energy resource meeting global energy challenges in a reasonable way", 2002. Energy Policy 30: 1261-1265.

Herzog, A.V., Lipman, T.E, Kammen, D.M., "Renewable energy sources", 2004. http://www.eolss.com.

IEA (International Energy Agency), Energy policies of IEA Countries, Turkey 2001 Review, 2001, IEA/OECD, Paris, France.

IEA (International Energy Agency), World Energy Outlook 2002, 2002, IEA/OECD, Paris, France.

Kaygusuz, K., "Hydropower and biomass as renewable energy sources in Turkey", 2001. Energy Sources 23: 775-799.

Kaygusuz, K., "Renewable and sustainable energy use in Turkey: a review", 2002a. Renewable and Sustainable Energy Reviews 6(4), 339-366.

Kaygusuz, K., "Environmental impacts of energy utilization and renewable energy policies in Turkey", 2002b. Energy Policy 30: 689-698.

Kaygusuz, K., "Hydropower and the World's Energy Future", 2004. Energy Sources 26: 215-224.

Kaygusuz, K., Yuksek, O., Sari, S., "Renewable energy sources in the European Union: Markets and capacity", 2006, Energy Sources (accepted for publication).

Koch, F. H., "Hydropower the politics of water and energy: introduction and overview", 2002. Energy Policy 30: 1207-1213.

MENR (Ministry of Energy and Natural Resources), Energy Statistics of Turkey, 2004, http://www.energy.gov.tr

Paish, O., "Small hydro power: technology and current status. Renewable and Sustainable Energy Reviews", 2002 6(6), 537-556.

Punys, P., "Small hydro power in the New EU Member States", 2004. Hidroenergia 04. Falkenberg, Sweden.

RTLED (Report of Turkey Long Term Electric Energy Demand), 2004.Ministry of Energy and Natural Resources, Ankara, Turkey,1-81 (in Turkish).

Yuksek, O., Ucuncu, O., Basic Hydrology with Solved Problems, 1999. Karadeniz Technical University Civil Eng. Dept, Trabzon, Turkey, 1-142 (in Turkish).

Yuksek, O., Kaygusuz, K., "Small hydropower plants as a renewable energy source", 2006. Energy Sources, Vol:1, No:3, 279-290.

Yuksek, O., Komurcu, M.I., Yuksel, I., Kaygusuz, K., "The role of hydropower in meeting Turkey's electric energy demand", 2006, Energy Policy, 30, 3093-3103.

Yuksel, I., Yuksek O., Onsoy, H., "An analysis of production hydroelectric energy in the Eastern Black Sea Region's Streams", 2005, International Symposium Water for Development Worldwide, 7-11 September 2005, Istanbul, Turkey, 115-123.

APPLICATION OF POLYUREA COATING ON CONCRETE LINING OF INTERMEDIATE LEVEL OUTLET AT TEHRI DAM PROJECT – A CASE STUDY

Satish C. SHARMA
Director(Technical)

R.K.VISHNOI
Dy General Manager

Tehri Hydro Development Corp., Pragatipuram, Rishikesh (UA)
India – 249 201

ABSTRACT

Tehri Dam Project Stage-I has been constructed on river Bhagirathi, a tributary of Ganga, with an installed capacity of 1000 MW. Spillway structures of Tehri Dam Project in India are unique & complex which have been provided for the first time in its design and construction on any water resources project in India. The maximum velocity at the heel of spillway structures is about 45 m/sec. Adequate measures were implemented in the design of structures to ensure the safeguard against the adverse effects of high velocity. Concrete protection is one of these measures generally implemented in such cases. The field of concrete protection by way of any suitable coating is rapidly changing and its limits are constantly being stretched. The introduction of polyurea coating on the structures of intermediate level outlet of Tehri Dam Project, in order to achieve a host of structural and functional features, is one such attempt. The paper discusses the composition and the mechanical and functional properties of polyurea coating used on concrete lining of ILO at Tehri Dam Project. The experiments conducted for obtaining the desired properties, made it possible to decide for the application of Polyurea in abrasive conditions instead of the conventional epoxy mortar due to Polyurea's 5 times abrasion resistance capacity as compared to epoxy.