THE ROLE OF HYDRO ENERGY POTENTIAL FOR ELECTRICITY GENERATING IN TURKEY

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Abstract - The electricity generation resources of Turkey are dominated by fossil fuels. In 2010, the 65% of total installed capacity is based on fossil fuels. Among them, natural gas has the largest share with 36,4% of total installed capacity. In 2012, Turkey's total electricity generating capacity was 56.1 million kilowatts and total net electricity generation was 228 billion kilowatt-hours. Turkey's electricity demand grew by more than 90% from 2001 to 2011. In Turkey, although demand fell in 2009 compared with the previous year because of the economic slowdown, in 2010 consumption increased by about 10% compared with the previous year. However, renewable energy usage by government and private companies is likely to increase year by year. This is not enough to reach the target of country. But the Republic of Turkey Government is aware of this situation. For this reason, The Turkish Government has developed some projects and investments in the last decade. In Turkey between 2010 and 2016, exactly 99 dams, hydropower plants (HPP's) and small hydropower plants (SHPP's) were constructed by government and some private companies. All of these were put into operation at the end of 2016. On the other hand, although Turkey does not currently generate any electricity from nuclear power, the government has been advocating construction of nuclear power plants in an effort to diversify Turkey's electricity supply portfolio.

Index Terms - Electricity Generation, Energy Potential, Energy Market, Hydropower, Turkey.

I. INTRODUCTION

1.1 Hydropower Global Generation

Global hydropower generation during the year 2013 was an estimated 3,750 TWh. About 40 GW of new hydropower capacity was commissioned. Increasing total global capacity by around 4% to approximately 1,000 GW. By far the most capacity was installed in China (29 GW), with significant capacity also added in Turkey, Brazil, Vietnam, India, and Russia. Growth in the industry has been relatively steady in recent years, fueled primarily by China's expansion. Modernization of ageing hydropower facilities is a growing global market. Some countries are seeing a trend towards smaller reservoirs and multi-turbine run-of-river projects. There also is increasing recognition of the potential for hydropower to complement other renewable technologies, such as variable wind and solar power [1], [2].

1.2 Hydropower Industry and Hydropower Global Capacity

Hydropower capacity additions in the five-year period end-2008 to 2013 were significantly greater than during the previous five years. However, despite a significant jump in new capacity in 2013, the intake of new orders for some major companies declined relative to 2012. For example, Andritz Hydro (Austria) reported that both sales and new orders were down from very high levels in previous years, although project activity was deemed satisfactory for small-scale hydropower. New orders were down for Voith Hydro (Germany) as well. Sales increased by 6% in the 2012-2013 fiscal year, but the market was below Voith's expectations. However, the company noted that the market for plant modernization is a major driver of new orders in many regions. Voith also announced advances in the area of very large generating units (such as the 784 MW turbines supplied to the Xiluodu plant in China), as well as small in-stream and low-head units, such as its prototype Stream Diver.

Alstom (France) noted a slowdown in demand for new capacity but growing demand for rehabilitation of the ageing stock of existing plants. Aiming to strengthen its capacity in China, Alstom inaugurated its upgraded hydropower industrial site in Tianjin, which supplied four 800 MW Francis turbines to the Xiangjiaba plant in 2012–2013. Alstom also inaugurated a global hydropower technology center in Grenoble, France, for all of its hydropower R&D. Dongfang's (China) production of hydropower turbine-generators was reported to be 4.2 GW in 2013, up 28.6% from 2012. A company highlight for the year was installation of a 770 MW unit at the Xiluodu plant. Harbin (also in China) produced 3.2 GW of hydropower turbine-generators during the year, a decrease of 3.7% relative to 2012 [1], [2].

1.3 Hydropower Capacity and Hydropower Development in Turkey

At the present, the largest hydropower project currently underway in Turkey is the 1200 MW Ilısu Dam, part of the Southeastern Anatolian Project (GAP) on the Tigris in 2014. It will create a reservoir with a volume of 10.4 billion m^3 and a surface area of

313 km^2 and is expected to produce about 3800 MWh a year.

Similarly, the 540 MW Yusufeli Dam is planned to be built on the Chorakhi (Çoruh) River located in the eastern Black Sea region. It is expected to produce 1705 MWh a year. 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 [3].

The hydropower industry is tackling projects of ever-larger capacity, and manufacturers are setting new records for capacity of individual turbines (≥800 MW per unit). At the same time, there are indications of a trend towards reduced reservoir capacity and the development of multi-turbine run-of-river projects, as seen in Brazil. As part of this trend, the industry has been developing more-flexible turbines that can adapt to varying flow rates. The use of multiple in-stream turbines in place of few large ones requires different technology, materials, and expertise. Another trend is the rise of regional approaches to system development, including interconnection, and a view of hydropower as complementing other renewable energy technologies. Figure 1 and 2 show hydropower global capacity, shares of top six countries and hydropower capacity and additions, top six countries for capacity added, 2013 respectively [1], [2].

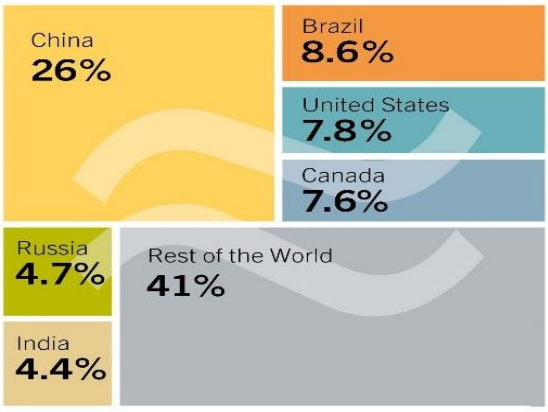


Fig. 1. Hydropower global capacity, shares of top six countries, 2013.

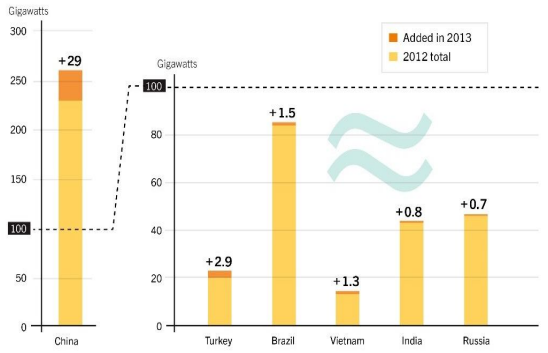


Fig. 2. Hydropower capacity and additions, top six countries for capacity added, 2013

II. ENERGY AND HYDROPOWER IN TURKEY

With its high dependence on imported fuels and electricity demand growth topping 7% a year, Turkey is increasingly turning to development of its domestic resources to meet demand. Coupled with its favorable geography, these factors have seen a swathe of hydropower development. Indeed, benefitting from its mountainous landscape and position between three seas, Turkey has a significant hydropower capacity, estimated at some 433 TWh a year in total, of which some 140 TWh a year is thought economically viable. To put this in context, according to Turkish Electricity Transmission Corporation figures electricity demand is expected to reach around 420 TWh annually by 2020. At an average elevation of 1,100 meters above sea level, with the Euphrates and Tigris River basins sitting at around 1,300 meters, there is ample head available for development in a number of regions, including the area around the Black Sea, the Mediterranean, and Eastern Anatolia. The country has a volume of some 186 km^3/year of water flowing through its 177,000 km of rivers in five separate watersheds [3].

III. HYDROPOWER AND ENERGY POLICIES IN TURKEY

Despite the considerable development of Turkey's abundant hydropower and other renewable resources, the country's energy mix is still dominated by fossil fuels. Currently gas supplies around a third of the country's total primary energy demand, while coal and oil products provide 27% and 29%, respectively. Much of the country's oil and gas comes by way of imports from Iran and Russia. Hydropower, wind and other renewables produce around 17% of Turkey's electricity supply. Other reforms centered on the liberalized electricity market accelerated private investment in Turkey's energy sector and by 2012, independent power producers were supplying some 26 TWh of energy annually. In addition, the government established a target to deliver 30% of its primary energy demand from renewables by 2023 [3].

In generally, there are three main categories to achieve the necessary policy in the energy issues. The first category, regulation, concerns both the means of devising regulatory frameworks on energy and the overarching goal of such policies. The second category also comprises two variables: the relationship between technology and risk and the nature of technology implementation. Finally, the category of political outlook comprises a discursive alignment and outlook on the nature of international relations [4]-[6].

Using these three categories, it is possible to construct a matrix of the competing energy and environment discourses in Turkey. For the sake of simplicity, this chapter uses only two major orientations, though a

variety of combinations are possible. These do not necessarily correspond with real world actors as the matrix is merely intended as a heuristic device to chart the profile of the ongoing policy debates in Turkey. Naturally, the real world of energy politics has various shades of gray, and it is not uncommon for actors to borrow from each camp over time. Nevertheless, these two positions, Greens and Developmentalists, capture the tenor of the ongoing debate in Turkey [4], [7]. There are two dominant factors to establish energy policy

The firs factor: Greens believe in extensive environmental regulation. In line with their European and North American counterparts, Greens in Turkey articulate their positions with an implicit critique of markets that question both their desirability as social institutions and effectiveness as regulatory tools. Thus, this position is characterized by calls for the direct involvement of the state in protecting the environment through command-and-control mechanisms. Moreover, Greens privilege ecological protection over continued economic growth. This is not to suggest that this position rejects economic growth entirely, since such deep ecology-inspired movements in Turkey remain relatively rare. The practical upshot of this for their energy policy is built around small-scale and alternative technologies, such as wind farms and solar panels. Finally, in their political outlook, the Greens in Turkey parallel the 'liberal' school of international relations, constructing their discourse around concepts such as multiculturalism and universal human rights, believing on the one hand that non-state actors are increasingly important in energy politics and on the other interpreting the interstate system as one characterized by win–win cooperation.

The Second factor: Developmentalists believe in minimum state involvement in the economy, including the environmental regulation of energy procurement and consumption. When regulation is necessary, the preferred method is through market-based mechanisms and to secure unbridled economic growth. They are characterized by their belief in the Promethean promise of risk-prone technologies, such as nuclear power. Where new technologies are not adequate or appropriate, conventional mega projects that are emblematic of both state power and its developmental goals are favored. Finally, when energy policy decisions intersect with issues of ethnic, cultural, or gender rights, Developmentalists follow a nationalist approach closely matched by the realist school of international approach, prioritizing state sovereignty and national strategic goals over the rights of subnational groups or the rights of peoples in other nation-states. As a corollary, the Developmentalist position takes a dim view of international cooperation, believing zero-sum outcomes to be the norm [4], [7].

The differences between these two positions can be demonstrated clearly by evaluating the ongoing debates on electricity procurement and consumption. By focusing on this emblematic issue, the section demonstrates how the tension between the Greens and the Developmentalists resonates through the entire spectrum of Turkish energy politics and policy. Growing at nearly 10% per annum, electricity procurement emerges as the single biggest challenge to energy politics and policies in Turkey [4], [8]. Persistent and unpredictable power cuts are reminders of the nation's growing electricity shortage. Therefore, nearly 82% (US$ 56 billion) of Turkish energy-related expenditure until 2010 will be allocated to electricity [9]. This translates into an annual investment of US$ 4-5 billion, expected to continue well into the 2020s.

Hydropower, already making up about 40% of the country' electricity production and slated to rise exponentially over the years. Since the inception of an ambitious and continued dam construction program in the 1930s, Turkey has constructed 202 large and 317 small dams; 114 of these dams also operate as hydroelectric power plants (HEPP) and over 200 new HEPPs of varying sizes are either in construction phase or are being planned. Until the mid-1980s, plans for dam construction remained largely outside the political sphere and were treated mainly as technical decisions. However, the progressive development of democratic politics in southeastern Turkey, where the majority of these dams are being constructed, have finally politicized the link between the growing need for electricity and the necessity of dam construction [4], [10]-[12].

The Developmentalist position on this issue is characterized by the stance it takes on the Southeastern Anatolia Project (GAP in its Turkish acronym), a complex network of dams and irrigation channels. Although current justifications for this mammoth project mention irrigation and regional development as key objectives, the earlier plans were articulated squarely in terms of providing a secure electricity supply. Techno-scientific optimism, belief in megaprojects, and willingness to put economic development over other policy objectives characterize the Developmentalist view on GAP [4].

IV. GAP FACTOR IN ENERGY POLICY IN TURKEY

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 hectare 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. For this purpose, total 12 groups of projects were planned on the Euphrates and Tigris rivers and their branches by the General Directorate of State Hydraulic Works [4], [13], [14].

The package included the construction of 22 dams, 19 hydroelectric power plants and the irrigation facilities to serve 1.7 million hectare 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 hectare of land. Fourteen 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 [15]. The Lower Euphrates Project is one of the GAP schemes on the Euphrates river and consists of Atatürk Dam and Hydroelectric power plant (HEPP), Şanlıurfa tunnels and hydroelectric power plant, Sanliurfa-Harran irrigation, Mardin-Ceylanpinar irrigation, Siverek-Hilvan pumped irrigation. Main public investments in this project have been completed. Atatürk dam was completed in 1990 which the sixth largest-volume dam (48.7 billion m^3) in the world. Type of dam is rock packed with 169 m high from river bed and 1664 m crest long. Body packed volume of the dam is 84.5 million m^3. Water reaches from the Atatürk dam to Şanlıurfa-Harran plains via the Şanlıurfa tunnels system, which consists of two parallel tunnels each 26.4 km long and 7.62 m in diameter. This irrigation tunnel system is the largest of its kind and it has numerous irrigation networks, canal systems constitute the physical groundwork in water resources. Tunnels were completed in 1997, and irrigation is now practiced in a 250 000 hectares; (total is 476 000 ha) [4], [13], [14].

V. ENERGY MARKET IN TURKEY AND HYDROPOWER DEVELOPMENT IN TURKEY

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. Indeed, he highlights the potential for additional hydropower investment even while the market for new-build projects is decelerating: "What might come out of this situation is a shift to the rehabilitation market. The base for hydro is already very big and they will be sold by the government and acquired probably quite a lot in the coming years. So that might give burst to a rehabilitation market. Certainly, the government continues to pursue its market liberalization programme and with it the privatization of the bulk of the nation's existing hydropower assets. It plans to move to a fully deregulated electricity market by 2015. The most recent figures available note that of 613 offers to privatize hydroelectric plants the treasury has achieved an overall revenue of more than $427 million. For example, the privatization process for 52 hydroelectric power plants belonging to the state-owned Electricity Generation Company (EÜAŞ) divided the assets into 19 groups for the purpose.

Hydroelectric power facilities were first developed in the region in 1935, and their development increased steadily until 1974, when the rapid growth in natural gas generation shifted the focus away from hydroelectric power development. Currently, 22.8% of all electricity generated in the country comes from hydropower, according to data from the International Energy Agency [3].

Turkey has 478 installed hydropower plants located in 69 provinces throughout the country, with a total installed capacity of 15.1 GW. Of these, 12.6 GW of capacity come from hydro plants and dams that impound reservoirs, and 2.5 GW are from run-of-river projects, according to the IEA. There are 534 plants currently being planned, with 160 of those under construction at around 15 GW of capacity. A primary draw for investors interested in developing Turkish hydro is the high energy cost in the country. The consumer price of electricity in domestic markets alternates between 16 and 17 US cents/kWh (varies based on time of day), which reduces the repayment period on the investment. The regional advantages, supportive political environment, and opportunities for exporting energy are all positives.

Beyond the high power prices the region offers experienced and reputable engineering and consulting companies, with the capacity to investigate potential sites, perform feasibility studies, design infrastructure tailored to the area, prepare bidding documents and offer site supervision services. The low-cost labor force and large portfolio of civil and mechanical engineers working in the field of hydropower in Turkey have been attractive to investors and developers alike, as have the ease of communication, money transfers, and international banking systems which are in place. Furthermore, all the civil works construction materials and goods can be provided

from within the province where the project is being developed or from nearby provinces, thus decreasing shipping costs during the construction phase [3].

VI. ELECTRICITY GENERATION, DEMAND AND SUPPLY IN TURKEY

Turkey's high dependency on fossil fuels (mostly imported) is not sustainable energy policy for sustainable development [16], [5]. As an industrializing country, the energy supply is vital for economic growth of Turkey. Any price increase or problem in supply of oil or natural gas will have immediate negative impacts on its economy and electricity generation [16], [17]. The large share of fossil fuels in electricity mix is also one of the main reasons of increase in GHG emission for last two decades. In order to decrease GHG emissions, the share of renewable sources in electricity generation needs to be increased [16], [8].

The latest published projection of Turkish Electricity Transmission Company (TEIAS) which is the national authority responsible for preparation of long-term electricity demand and supply projections is valid for the period of 2009-2018. The projection of TEIAS is based on different scenarios for demand and supply. In supply analysis; existing capacity, power plants in construction phase and projects with energy licenses are considered. According to this projection, reliable generation of power plants will not be sufficient to cover electricity demand by 2015. In other words, if new capacities such nuclear and wind are not installed and operated in coming years, Turkey is expected to face significant electricity shortage by 2020 [16], [18], [5]. Present and future installed electricity capacity by energy sources is given in the Table I. According to the projection, the share of hydro capacity will be highest with 37,4% and share of natural gas will be 32,6% [16], [5], [6], [17], [19]-[21]. Renewable energy supply for at the present and in the future in Turkey is given in the Table II [5], [6].

Energy source	2010	2012	2014	2016	2018	2020
Lignite	8 280	8 280	8 280	8 280	8 280	8 280
Hard coal	560	560	560	560	560	560
Imported coal	1 840	3 470	4 680	4 690	4 690	4 690
Natural gas	14 840	17 560	18 400	18 400	18 400	18 400
Geothermal	90	90	90	90	90	90
Fuel oil	1 900	1 900	1 900	1 900	1 900	1 900
Diesel	220	220	220	220	220	220
Other	260	260	260	260	260	260
Thermal total	27 990	32 340	34 390	34 400	34 400	34 400
Biogas + Waste	62	70	70	70	70	70
Hydropower	16 393	19 880	19 880	21 094	21 094	21 112
Wind energy	810	1 030	1 030	1 030	1 030	1 030
Total (MW)	45 255	53 320	55 370	56 594	56 594	56 612

Table I. Present And Future Installed Electricity Capacity By Energy Sources (MW)

Renewable energy sources	2000	2005	2010	2015	2020
Primary energy supply					
Hydropower (ktoe)	2 656	4 067	4 903	7 060	9 419
Geothermal, solar and wind (ktoe)	978	1 683	2 896	4 242	6 397
Biomass and waste (ktoe)	6 457	5 325	4 416	4 001	3 925
Renewable energy production (ktoe)	10 091	11 074	12 215	15 303	19 741
Share of total domestic production (%)	38	48	33	29	30
Share of TPES (%)	12	12	10	9	9
Generation					
Hydropower (GWh)	30 879	47 287	57 009	82 095	109 524
Geothermal, solar and wind (GWh)	109	490	5 274	7 020	8 766
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					
Geothermal, solar and wind (ktoe)	910	1 385	2 145	3 341	5 346
Biomass and waste (ktoe)	6 457	5 325	4 416	4 001	3 925
Renewable total consumption (ktoe)	7 367	6 710	6 561	7 342	9 271
Share of total final consumption (%)	12	10	7	6	6

Table II. Renewable Energy Supply In Turkey

The share of sources in electricity generations for 2018 and 2020 are also given in Figure 3. As it can be seen in the figure, the natural gas share will be the highest with 42,7% and the share of total fossil fuel will be 75,4%. The projection shows that Turkey's fossil fuel dependency will continue at least for a mid-term period. Even though the hydro capacity will increase, non-hydro renewables such as wind, solar, geothermal and biomass are expected to remain fairly low with a 1,5% share in the total generation [16], [17], [5], [20].

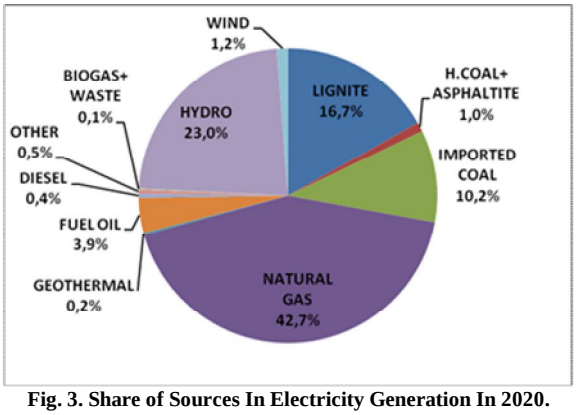


Fig. 3. Share of Sources In Electricity Generation In 2020.

CONCLUSION

This study shows 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. Hydropower has an extensive list of positive characteristics. In addition to power generation and efficiency, it has advantages such as: flood protection, flow regulation, multiple use, fossil fuel avoidance, a long depreciation period, revenue by an adequate electricity rate, and low operating-maintenance-replacement costs.

In view of the low operational costs of hydropower, related to not having any fuel expense, hydro plants can easily fit load demand, while having a long economic life and low environmental impacts compared with alternative energy resources. Additionally, hydro plants with large reservoirs have multipurpose benefits and profitability, such as flood protection, storing water for domestic water supply, industry and farms, fisheries, navigation, access roads and the potential for a previously inaccessible and remote area to develop economically. On the other hand, 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.

ACKNOWLEDGMENTS

This study was supported by Yildiz Technical University, Scientific Research Coordinator, Istanbul, Turkey. Project ID: 1897, Project Number: 2016-05-01-KAP01.

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