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A comparative study on energy income estimation: A case study in Turkey

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ABSTRACT

Hydropower is the main domestic energy resource of Turkey. The total gross and the economically feasible hydropower potentials of Turkey are estimated as 433 TWh/yr and 127 TWh/yr, respectively, by the General Directorate of State Hydraulic Works (DSI) of the Ministry of Forestry and Water Affairs.[1] Approximately 35% of the economically feasible hydropower potential is currently being utilized. The government accelerated the development of the unused potential by enabling the private sector to build and operate hydroelectric power plants. The primary goal of a feasibility study is the determination of the best installed capacity through economic analysis, which is based on evaluation of energy incomes and investment costs associated with alternative installed capacities. Generally, it is relatively easy to realistically estimate the investment costs. On the other hand, energy income estimation is not a straight forward process; a number of different methods which result in different income estimates are being used in Turkey. The General Directorate of Renewable Energy (YEGM) of the Ministry and Natural Resources and DSI recommend similar methods for energy income estimation based on firm and secondary energy generations. However, suggested unit prices for firm and secondary energy generations by DSI and YEGM are quite different, which results in different energy income estimations. Apart from these two methods, consultancy firms, unlike DSI and YEGM, use a single unit price for energy without making any distinction between firm and secondary energies. In all three methods fixed energy prices are used. Nevertheless these approaches do not represent the current situation in Turkey, since the electricity market allows development of hourly electricity prices. In this study, a new energy income estimation method which utilizes hourly electricity prices, called the Variable Price Method is developed. Results of these four methods are compared for a case study, namely Altiparmak Hydroelectric Power Plant.

Contents

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1. Introduction

Hydropower is Turkey's main domestic energy resource. DSI is the primary responsible executive state agency for planning, operation and management of water resources in the country. According to DSI, approximately 65% of the economically feasible hydropower potential of Turkey is undeveloped [1]. This makes the funding of hydropower projects by the private sector very important in developing countries, such as Turkey [2]. Therefore, the government accelerated the development of the unused hydropower potential [3] by enacting the Electricity Market Law no. 4628 in 2001 [4], which enables the private sector to build and operate hydroelectric power plants. Moreover, with the publication of the Renewable Energy Law no. 5346 in May 2005 [4], the government guarantees the purchase of electricity from production companies at a price of 7.3 US cent/Kwh for 10 years. As a result of these laws, investments in hydroelectric power plants (HEPPs) increased and the number of HEPP projects under the planning and construction stages reached 1084 and 256, respectively [5]. A summary of HEPP projects in Turkey is shown in Table 1.

Before any HEPP project is constructed, a feasibility study needs to be conducted. Such assessment is commonly carried out by a private engineering company or a consultancy firm. An economic analysis is carried out in the feasibility study to determine the best installed capacity for the HEPP. The economic analysis is based on the evaluation of energy incomes and investment costs associated with alternative installed capacities. Generally, it is relatively easy to make realistic estimates of a HEPP's investment cost as this can be estimated from construction unit prices determined by DSI or by using bids collected from the market. On the other hand, energy income estimation is not a straightforward process; a number of different methods, which result in different income estimates, are being used in Turkey.

The General Directorate of Renewable Energy (formerly called General Directorate of Electrical Power Resources Survey and Development Administration, EIEI) and DSI recommend similar methods for energy income estimation based on firm and secondary energy generations [6]. However, firm and secondary energy generation unit prices suggested by both YEGM and DSI are quite different, which results in different energy income estimates. Apart from these two methods, private engineering companies and consultancy firms, unlike these two government bodies, use a single unit price (hereafter referred to as Single Price Method, SPM) for energy income estimation without making any distinction between firm and secondary energies. For example, both Hidromark and Eser Project, prominent Turkish private companies in the sector, used single unit price for energy in the feasibility studies they carried out for Balkusan and Ekincik HEPPs, respectively [7,8].

Each consulting company is free to conduct HEPP feasibility analyses with the fixed price of its choice. Due to free market principles, DSI imposes no restrictions on such price. Ideally, consulting companies investigate previous electricity prices and choose reasonable price estimates to use in their feasibility studies. However, such an arbitrary approach results in the utilization of different price estimates by different companies for different projects. Moreover, starting in December 2009, the Turkish electricity market has undergone a comprehensive structural change with the enactment of the Day Ahead Planning and Balancing Power sub-markets [9]. Thus, since early 2010, hourly electricity prices have been used for electricity trading. Given such reforms, we believe the integration of hourly electricity prices into feasibility analyses will result in more realistic energy income estimates for HEPPs. As such, this study develops a new energy income estimation method that uses hourly electricity prices, the VPM. As a case study, economic analysis for two different formulations of Altiparmak HEPP is carried out using four different energy income estimation methods, namely the SPM, the YEGM method, the DSI method and the VPM, and the results are compared.

Table 1
HEPP projects in Turkey [5].

Potential	Number of HEPP	Total installed capacity (MW)	Average annual generation (GWh/Year)	Percent (%)
In operation	303	17,372	62,000	38
Under construction	256	10,590	35,000	21
Project phase	1084	19,535	67,000	41
Total	1643	47,497	164,000	100

2. Altiparmak dam

The potential of renewable energy sources in Turkey is large and hydropower represents a great portion of it [10–13]. Currently, there are many hydropower projects in the design and construction stages in Turkey [14,15] and Altiparmak HEPP is one, currently in its design stage. This project aims to develop the hydropower potential between the elevations of 1230 m and 840 m of Parhal Stream, a branch of Coruh River in Artvin [16]. YEGM and ANC Energy, a private company intending to construct this power plant, have developed two alternative formulations for the Altiparmak HEPP as shown in Fig. 1. Fig. 1 shows how ANC Energy recommended a relatively different model to that proposed by YEGM, in order to shorten the construction time and the costs of dam body and expropriation [17]. YEGM formulation is composed of an arch dam whose thalweg elevation is 1095 m. The power plant is located at Sarıgöl and a 6785 m long energy tunnel connects the reservoir to the power plant. The length of the penstock is 467 m. On the other hand ANC planned a roller compacted concrete dam at a thalweg elevation of 1160 m. The energy tunnel and the penstock lengths for ANC formulation are 8635 m and 687 m, respectively. Basic characteristics of these formulations are shown in Table 2.

As shown in Table 2, the optimum installed capacities recommended by YEGM and ANC Energy for the Altiparmak HEPP are 50 MW and 70 MW, respectively. Although the formulations are similar to each other, the estimated optimum installed capacities are different. The reservoir storage capacity of the YEGM project is bigger than that of the ANC Energy project. Therefore, the inflow can be regulated more efficiently with the YEGM formulation; so its optimum installed capacity is expected to be higher. However, as can be seen from Table 2, ANC Energy recommended a higher installed capacity for the project. This discrepancy arises from the utilization of two different energy income estimation methods. ANC Energy used a fixed price (8.25 US cent/kWh) for estimating the energy income. As explained before, YEGM used its own method which utilizes lower unit prices for firm and secondary energy generations.

3. Feasibility level economic analysis

Most efficient utilization of hydropower energy requires identification of the best installed capacity of a HEPP through economic analysis [18–20]. In the economic analysis, design discharge alternatives are identified first and then the corresponding alternative installed capacities are calculated. Different alternative installed