MONETIZATION OF HYDROPOWER DAM PROJECTS

SHASHANK DWIVEDI
M.Tech Student, Department of Hydro and Renewable Energy, Indian Institute of Technology Roorkee

ARUN KUMAR
Professor, Department of Hydro and Renewable Energy, Indian Institute of Technology Roorkee

ABSTRACT

The world is shifting its focus from conventional energy sources to renewable energy sources such as hydro, solar, wind etc to decarbonise the energy for mitigating the climate change. Hydropower projects provide many additional benefits other than electricity and these may be broadly classified into two services -Energy Management Services comprises energy generation, ancillary services etc. and Water management services incorporates services viz irrigation, water distribution and greenhouse gas emission etc. These services, if monetised will provide a more robust approach for analysis in terms of viability. This paper is about monetising these benefits and the case of Tehri Multipurpose dam based Project has been studied. To monetise energy management services, Linear Optimization Technique has been applied on GAMS software and the value obtained for these services are found INR 4.20 per kWh. The overall value of water management services is found out INR 5.58 per kWh. Thus, the overall monetised value for the Tehri Hydropower project is assessed to be INR 9.78 per kWh out of which major portion of the benefits comprises of water management services.

1. INTRODUCTION

World's population is expanding at a high rate leading to an increase in the energy requirements at the same rate as the Human Development Index (HDI) is correlated with the per capita energy consumption. Out of total energy production, major portion of energy is being produced by thermal power plant (TPP) in which coal is used as a fuel. As the amount of coal is limited and is being consumed in huge amounts and the by-products of coal also produce life threatening greenhouse gases which is depleting the atmosphere. Thus, it can be said that there is a huge demand for a clean source of energy which can be fulfilled by the renewable sources of energy that are available in abundance and do not harm the environment. Renewable energy accounts for 27.3% of the world's total energy consumption (Fig. 1). Also, the need of more and more clean energy is increasing the share of renewable energy. Hydro power is also a renewable source of energy as it uses non-consumptive water flow. It accounts for 15.9% share of world's total energy which is around 2357GW [1] currently which is the largest renewable source of world's grid connected energy technology.

Hydropower (water power) is the power that is derived from the energy of moving water from higher elevation to lower elevation harnessed for useful outcomes. Before using it to electric power, hydropower was used for irrigation as well as operation of water mills, textile machines and sawmills. Apart from energy generation hydropower plants are being used for other benefits like they are used for preventing floods and so on. A pictorial representation of these services is shown in Figure 2.

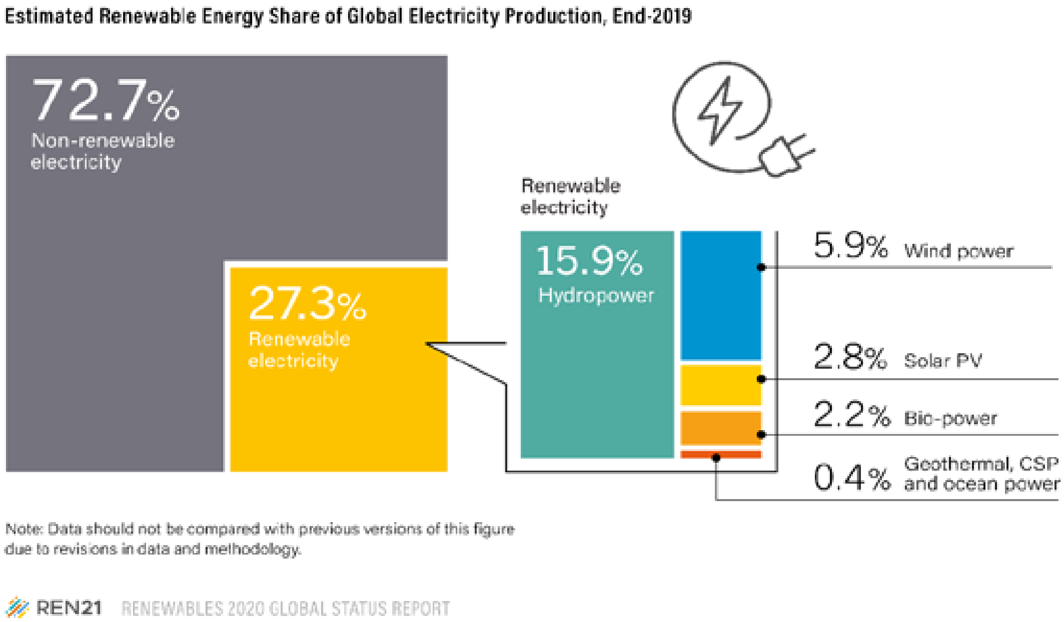

Fig. 1 : Renewable Energy Share[1]

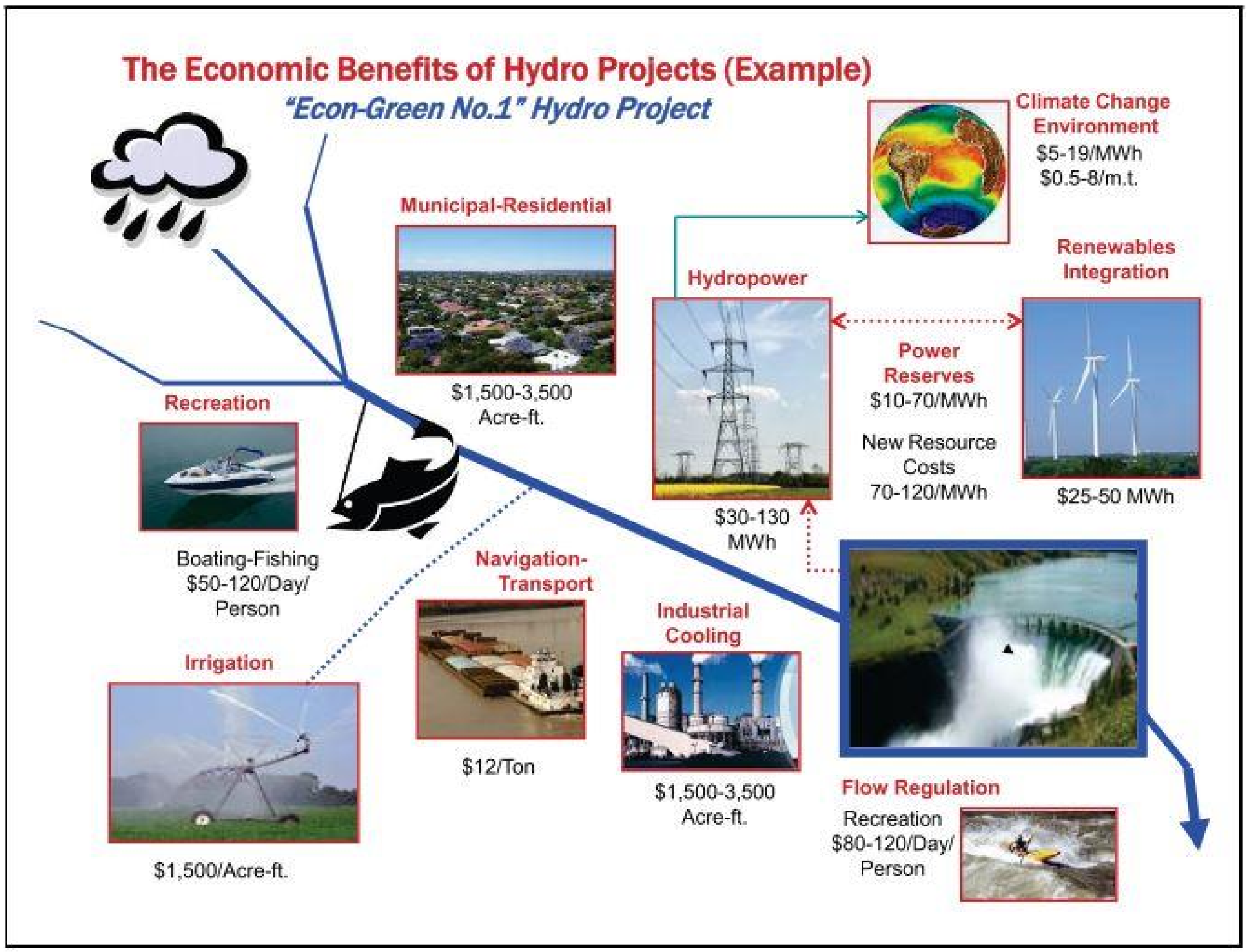

Fig. 2 : Services From Hydropower[2]

Apart from energy generation hydropower plants have other benefits like they act as barriers to flood, increases livelihood of the people living in the neighbourhood and many more.

Generally, these benefits are divided into two major categories i.e., Energy management services and water management services. Energy management service is needed for the proper operation of the power system. It is also needed to maintain the balance between demand and supply of electricity, enable electrical energy to be delivered safely, and maintain power system stability, reliably and economically from generators to consumers. Water Management Services and Other socio-economic services includes those services that provides benefits for the regional development in terms of infrastructure like schools, colleges, water use, proper irrigation to the land fields and electricity for the local development or equivalent amount of money should be feed into the local area.

2. LITERATURE REVIEW

Various researchers have studied the valuation and additional benefits provided by the hydropower in respect of energy and water management services worldwide and in India. IEA's work on Valuing Hydropower Services dt October 2017 made their studies on multipurpose hydropower projects. In this report, all the benefits from hydropower that will show the economic feasibility have been considered. They have also discussed the various methods which should be used for valuation from economics point of view[3]. IEA's work on Flexible hydropower providing value to renewable energy integration stated the role of hydropower and need for the flexibility in the future electricity system. [4].

As per EPRI report on Flexible Operation of Hydropower Plants stated clearly about the difference between base load operation and flexible operation and it also talked about the adverse effects of flexibility that increased the starting and stopping of units [5]. US department of the Interior Bureau of Reclamation Technical Service Centre in their report Hydrogenator start/stop cost stated the importance of quantifying the cost of ancillary services assisted by hydrogenators to support integration of variable renewable energy into the power system using both top-Down as well as Bottom-Up Strategy [6]. CEATI's report on quantifying the Non-Energy Benefits of Hydropower stated that the cost of an ancillary benefit is estimated by comparison with optimized operation that produces the same amount of energy and capacity without these constraints [2].

As per IHA's Hydropower Status Report analysed that replacement of hydropower with coal will generate additional 4 billion tonnes of greenhouse gases in 2017, and total emissions from fossil fuels would be 10% higher [7]. US Department of Energy in its report Hydropower Vision stated that already present hydropower has high value based on ability to provide water management; and social and economic benefits, air pollutants and GHG emissions as well as flexible generation and energy services; ancillary grid services[8]. In similar study of US department of energy stated hydropower is the primary purpose at only 2.5% of the approximately 87,359 federal dams across the country[9].

IRENA in its report Renewable Energy and Jobs stated that Global renewable energy employment reached 10.3 million jobs in 2018, an increase of 5.3% compared with the number reported in the previous year out of which in Hydropower is estimated to be around 1.5 million peoples out of which 63% are employed in operation and maintenance of hydropower[10]. Guiuan Wang et.al., has divided watershed ecosystem services into 4 categories and used 21 indicators. He has used various evaluation methods like market valuation method, travel cost methods, contingent valuation methods and find that the average environmental cost per unit of electricity is up to 0.206 Yuan/kWh and also find the cost of positive and negative services of hydropower[11]. Üllas Ehrlich et.al., studied about the Jagala Waterfall in Estonia and used Contingent Valuation Techniques to find out the monetary value of non-market value and this value comes out to be 10 million euros [12]. Andrei Briones-Hidrovo et.al., analysed a cost benefit analysis based on Ecosystem Valuation method (contingent valuation method) before and after the implementation of hydropower. It stated that these services should be consider and the cost of generation from hydropower should be USD 0.4520/kWh [13]. Siyuan Yang has studied economic ecological valuation of the Manwan Hydropower Plant and considered both positive as well as negative benefits based on various valuation [14].

National Renewable Energy Laboratory, POSOCO & Berkeley Lab in their work on Greening the Grid mentioned India's commitment to 175 GW of renewable up to 2022, and proposed two scenarios that suggest how renewable energy integration can help as well as interferes over the whole year [15]. As per Pawan Kumar et.al. the regulatory framework available for the ancillary services was introduced for the first time in India in 2015 and was implemented in April 2016. Ancillary services can be considering as one of the four important parts of market design; other three being imbalance handling, scheduling & despatch, and congestion management [16]. IEA in India 2020 Energy Policy Review stated that the government has targeted policy to increase the share of renewable electricity, with a target of 175 GW capacity by 2022. In addition, the Government of India is promoting hydropower as a source of flexibility and grid stability (it is now categorised as renewable energy and can be supported under hydro purchase obligations) [17]. Young stated that rate of carbon tax is a significant characteristic that is determining the impact that the tax will have on the carbon emissions [18]. Muthukumara and Zhang stated that India is moving from Carbon subsidy to carbon tax. Also, the Government of India revised its coal cess from INR 50 per ton to INR 100 per ton. So, this all can be saved easily by hydropower which will also add value to the system [19]

Research shows that the research conducted on hydropower for the effects and values of its services is very limited. Most of the analysis is based on theoretical approach to determine the value of hydro power and no real figures have been arrived. Important services such as ancillary services, ramping availability etc. are not considered in monetary terms. So monetising them will improve the financial feasibility of hydropower projects. The importance of services like flood & drought controls, irrigation, drinking water, navigation and fisheries etc. are considered loosely so monetising them will reinforce their importance. Support and security to grid provided by hydropower has not been monetised. Thus, the objective of the study is to review various past research work on various available services from hydropower and implement linear optimization techniques to monetise energy management services and contingent valuation method to monetise water management services using the case study of Tehri multipurpose project.

3. METHODOLOGY

The methodology adopted for the study is based on past research work as well as based on the valuation method used so to identify the that were been followed given from the guidelines of the Policy makers and wherever there is no such data is been given then their ecological studies and questionnaire will be used to monetise these benefits. The detailed description of the flowchart given figure 3 is been described in the following sections.

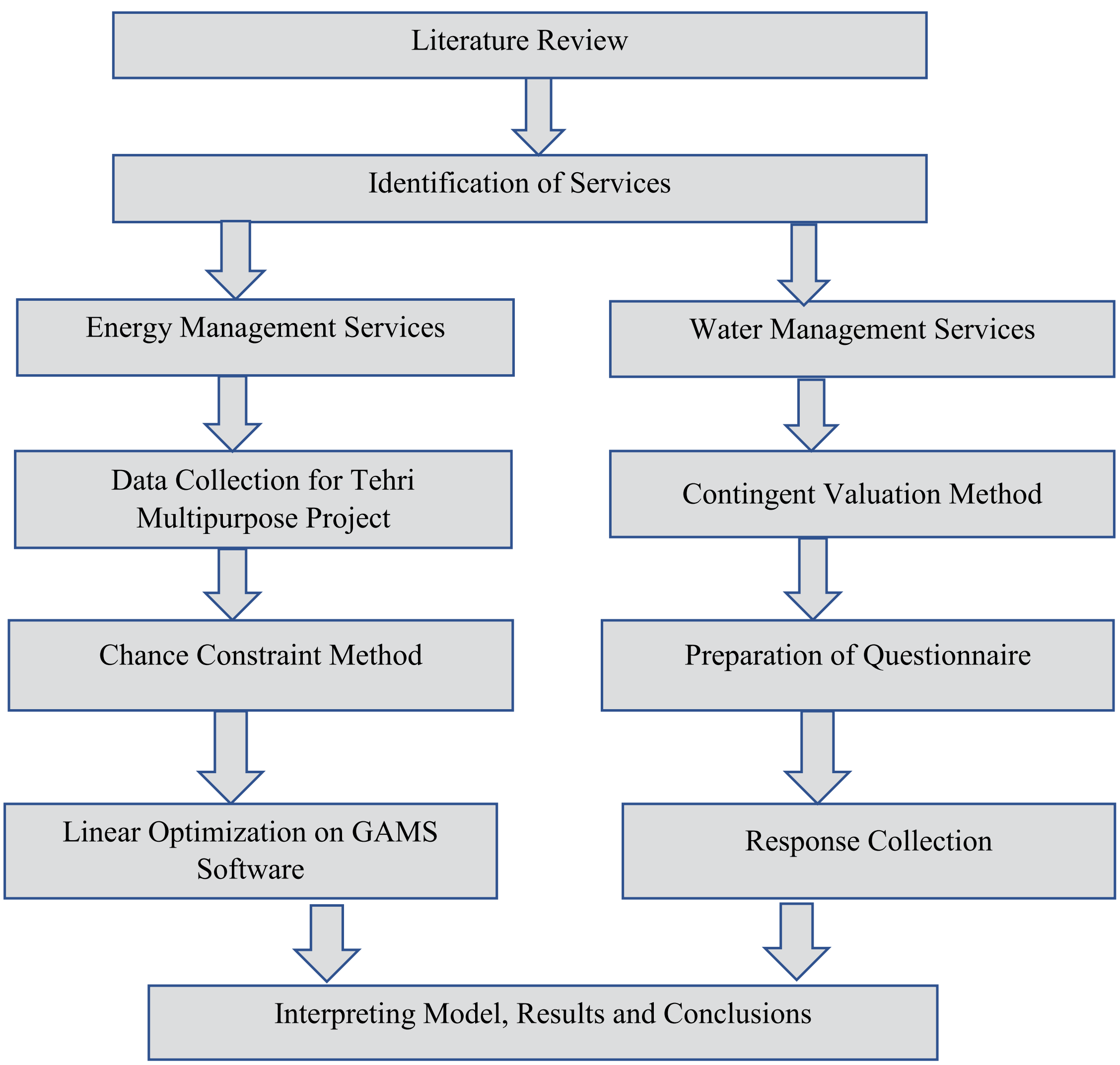

Fig. 3 : Flowchart of Methodology

A summary of different services provided by the hydropower projects are identified as described in Table 1.

Table 1 : Different Services provided by Hydropower projects

Main Division	Sub division	Services	Description
Energy Management Services	Bulk Power Services	Electricity Generation	Process of generating electrical energy from other sources of energy like chemical, tidal, solar, water etc.
		Energy Price Arbitrage	It is a process in which we buy energy at a time and place when the cost is low and sell it when the cost is high.
	Ancillary and Reliability Services	System Inertia	It is the stored energy in the system and it is provided by the rotational mass of generator.
		Frequency	It is real time changing variable that indicates balance between generation and demand and it includes both the automatic generation control and governor response.
		Energy Ramping	It is the ability of a generation facility to increase or decrease in output of power on the basis of change in demand from time to time.
		Voltage support	It uses reactive power controlling mechanism to put the transmission lines voltages at nominal levels.
	System Wide Effects	Black Start capability	It is the ability of a power generating module from a total shutdown.
		Integration of variable renewable energy	It is the practice of developing efficient methods to cope up with variable renewable energy by counterbalancing their variability.
Water Management Services	Water Quantity Management	Flood Control/ Drought Control	Flood is an overflow of water that submerges the area of land that is usually wet and drought is a condition in which low water becomes issue.
		Ground Water Stabilization	Some part of water which flows through channels infiltrate through the soil to increase the GW stabilization
	Water Quality Management	Increased water supply	With availability of planned water supply we can increase the water supply to the areas with low water supply
		Trash Removal	As hydropower already have trash removal mechanism, so it also reduces the trash in the channel.
		Sediment Management	As downstream of weir or dam can easily used for the sediment management as it is easy to flush and dredge the sediment from downstream portion.
	Regional Development	Recreation and tourism	These are the places available for various recreation activities like fishing, camping, swimming, and many more.
		Irrigation	Most of the farmer's land lies in the arid region with having lower rainfall than the average rainfall. So, irrigation networks are developed.
		Aquaculture	It is farming of fish and other species found in water.
	Human Development	Improved infrastructure	Persons residing near the site have additional benefits using better infrastructure available to them in form of better houses and roads.
		Livelihood	Persons residing near the multipurpose projects gets more involvement in different works available to get good livelihood.
		Domestic Power	It is an additional benefit to either give a specified amount of energy to the local area.
	Environment Goals	Reduction of GHG	As flow of water is used to generate energy so it reduces the generation of greenhouse gases.
		Creation of Wetlands	Areas where water covers soil, or it is present near of the surface of soil for different period of time during a year.

4. STUDY AREA

The Tehri Multipurpose Project consists of Tehri dam and three major hydropower projects and comprising of phase 1 with 1000 MW hydropower project and water release for the irrigation and municipality water supply and downstream of which is Koteshwar Hydro Electric Project of capacity 400 MW and pumped storage project of 1000MW capacity which is under construction. This study is focused on the Phase 1 of the project i.e. Tehri Dam of capacity 1000 MW project. For the study various hydrological data and irrigation demands and various levels of water are collected and various generation data have also been found out.

Tehri dam is an earth and rock fill with the height of 260 m and base width of 1128 m. The catchment area has normal annual precipitation in the range of 1016-2630 mm with maximum recorded flood as 3800 m3/s. The dam has been designed with the probable maximum flood (PMF) as 15,540 m3/s. The dam has a gross storage capacity of 3540 Million cubic meters (MCM) with live storage of 2,615 MCM.

5. LINEAR OPTIMIZATION

With the help of Linear optimization technique using General Algebraic Modelling software (GAMS), a model for multipurpose hydropower is developed and inflow to the reservoir is taken as random variable. Also, due to variation in water demand and level of reservoir, head on the turbines also get changed. The variables considered in the study are

In_t = random inflow in to the reservoir

St_t = Storage at the starting or beginning point of study

St_{t+1} = Storage after time t+1

Ep_t = Evaporation loss occurred in water at any time t

R_t = Downstream water release for the power generation at any time t

IR_t = Irrigation release at any time t

Reservoir Continuity Equation,

The continuity equation is developed and is written at any time t as Eq (1)

$$In_t + St_t - Ep_t - IR_t - R_t = St_{t+1} \qquad ...(1)$$

The evaporation losses are estimated using linear relationship Eq 2.

$$Ep_t = \alpha_t + \beta_t(St_t + St_{t+1}) \qquad ...(2)$$

where a and b are the coefficients depending on the time period t. By substitute the value of evaporation loss in the continuity equation, Eq 3 is obtained.

$$In_t + St_t - \alpha_t - \beta_t(St_t + St_{t+1}) - IR_t - R_t = St_{t+1} \qquad ...(3)$$

Rearranging the above equation to find the value of irrigation release, the equation becomes Eq 4.

$$IR_t = In_t + (1 - \beta_t)\ St_t + (1 + \beta_t)\ St_{t+1} - R_t - \alpha_t \qquad ...(4)$$

Reservoir release policy

This will be the base of the optimization problem to release water for irrigation which defines as the probability (Prb) of release of irrigation release in the time period t equalled or exceeded the irrigation demand, is not less than the specified value taken as P where P is defined as the reliability level[20].

Linear-decision rule for chance-constraint optimization

As inflow function is a random variable, one can plot the cumulative distribution function (CDF) of the inflow variable and one can get the reservoir inflow during time t with probability (1-P) which is said as $In_t^{-1}(1\text{-}P)$ as given in Eq 5.

$$(1 + \beta_t)\ bt - (1 - \beta_t)\ b_{t-1} + R_t + \alpha_t + ID_t <= In_t^{-1}(1\text{-}P) \qquad ...(5)$$

Other constraints

There will be other constraints too, which will be applied on the reservoir and on the power generation which are been shown as follows:

Power Plant Constraint

The energy produced by the turbine at any time interval t which is denoted as Et, will never exceed the installed capacity of turbine which is denoted as MP.

Storage Constraint

The water stored in any time t, shall not be more than the live storage (Tl) and less than dead storage (Td).

Head Storage Relationship

To calculate head over the turbine, reservoir elevation Ht, at any time t to be taken as the average of the elevation at the starting and end of the duration.

Objective function

The objective function is to maximize the annual hydropower generation subject to given constraints to find out the final dependability and maximum possible energy generation. To optimized the above energy generation General Algebraic Modelling Systems software has been used.

6. RESULTS AND DISCUSSIONS

6.1 Valuation of Bulk Power Services

Bulk Power Services includes mainly the generation of electricity from the hydropower and then selling in the market to get revenue. The valuation of electricity generation is a simple and straightforward process as it is dependent on the electricity prices and it can be monetised very easily. The formula used to monetise electricity generation is been given as in eqn.6.

$$\text{Value} = \text{Sum}\ (Pi*Ni) \qquad \text{...(6)}$$

Where Pi = Price of electricity generated bid on Indian Energy Exchange

Ni = Number of units committed to generate during the slot period.

For the calculation purpose, base year has been considered as from 01 April 2018 to 31 March 2019, number of units generated from the hydropower projects in the India has been shown in the figure 4. As the variation in the hydropower is seasonal due to unavailability of water, the daily value reaches to as low as 196 Million Units and where there is abundance of water these value reaches as high as 734 Million Units in the month of September.

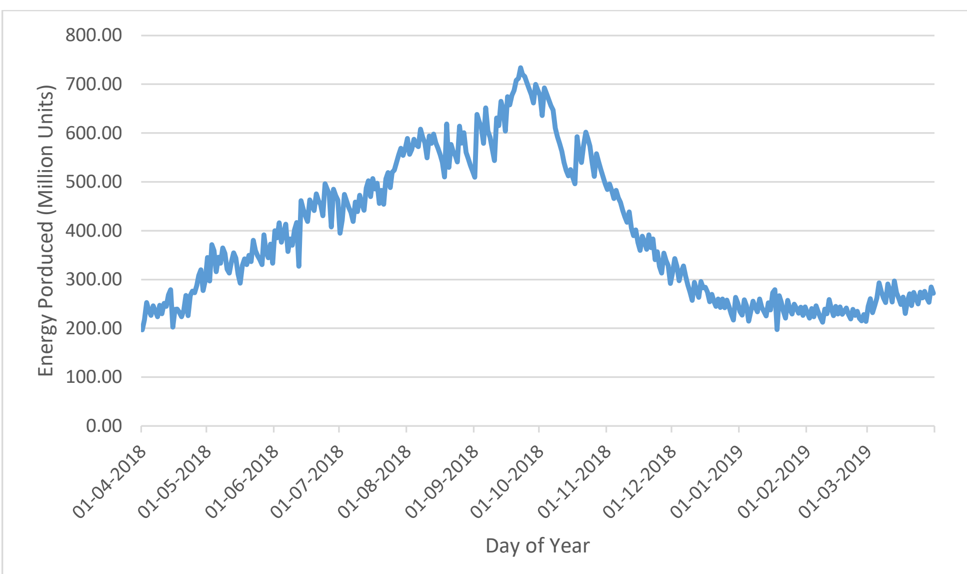

Fig. 4 : Energy generation Data for year 2018-19

The irrigation release data from the Tehri Reservoir for the Upper Ganga Canal and Lower Ganga Canal for the irrigation in the Uttar Pradesh has been given for the year 2009-10 is taken from UP irrigation department. Considering yearly increase in irrigation demand 0.5% per year, the irrigation release data for the base year 2018-19 has been given as below in the Table 2.

Table 2 : Irrigation Demand source: Uttar Pradesh Irrigation department

S. No.	Month	Irrigation Release for 2009-10 (Mm^3)	Irrigation Release for 2018-19 (Mm^3)
1	January	797	834
2	February	824	862
3	March	877	917
4	April	751	786
5	May	549	574
6	June	656	686
7	July	442	463
8	August	393	411
9	September	328	343
10	October	446	467
11	November	435	455
12	December	542	566

The installed capacity of the turbines in the Tehri Hydropower Projects is 1000 MW and the maximum energy generated for the one year duration considering 730 hours a month and considering plant load factor as 0.60 is 438 Million units per months that gives annual generation of 5256 million units of generation that is considered as the maximum limit for the generation.

The value of α and β (which are used in equation 2) are been derived from the storage vs surface area covered by the water in the Tehri reservoir. The average value of these are 3.86 and 0.0158 respectively.

After finding all the data, the model is been made and solved on GAMS software. GAMS is a General Algebraic Modelling System for mathematical optimization and for this software, linear optimization technique has been used.

Initializing the dependability year as 74.36 % which means that the percentage of time inflow values are equalled or exceeded the value as 419.33 Mm^3 as the first trial, and by running the optimization in the GAMS software the output for the energy generation is 2195.32 million units for the year.

The electricity prices for the month of April 2018 have been taken from Indian Energy Exchange and these prices has been considered as the average prices for the day. Every hour is been divided into time slots of 15 minutes for the bidding so the whole day is been is divided into 96 slots. The whole Indian grid is also been divide into The April 2018 prices are been taken for the whole year. The variation in the prices of electricity for the month of April 2018 is been shown in the Figure 5. The daily variation of the prices is been confined in between INR 3 to INR 5 per kWh.

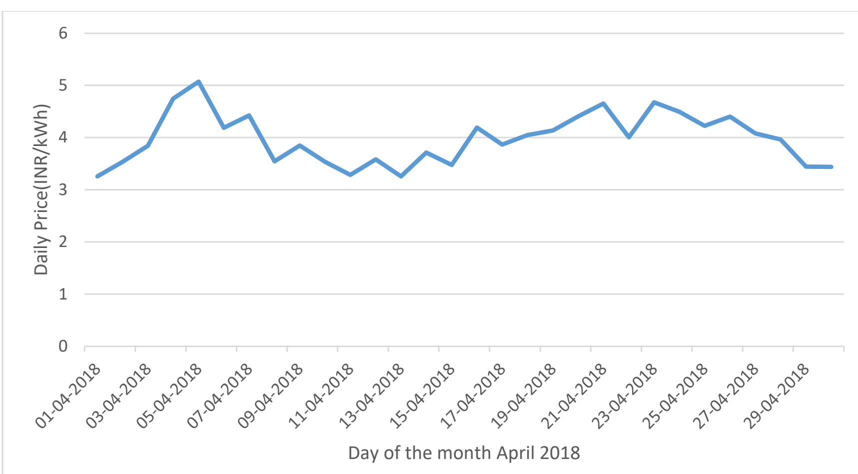

Fig. 5 : Daily Prices of Generation [Source: Indian Energy Exchange]

The revenue is calculated using Chance constraint Method for the year 2018-19 and works out to be INR 8,741 millions, 13,059 millions, 15,571 millions and 19,464 millions for the dependability 74.36%, 67.69%, 61.03% and 54.36% respectively.

6.2 Ancillary Services

Ancillary Services are those kinds of services which helps in operating the electricity grid in efficient and reliable manner. Few of the basic services are frequency regulation, ramping up and down and black start capabilities. The idea of ancillary services is been came up in CERC Indian Electricity Grid Regulations Code 2010 and it has been launched in Indian Grid firstly 18th April 2016[21]. CERC formulated Reserve Regulation Ancillary Service (RRAS) which has also created a Virtual Ancillary Entity for the respective SLDC and the prices for the ancillary services are also been considered. Tehri Hydropower Project is been taken into Northern Regional Power Committee and the major details for its ancillary services are been provided in table 3 [22].

Table 3 : RRAS parameters provided by Tehri hydropower Projects [22]

S.No.	Parameter	Data
1	Maximum Possible Ex-bus Injection(MW)	At reservoir level 789.0 m: 865MW At reservoir level 779.18 m: 597MW
2	Technical Minimum	125 MW
3	Fixed Cost (INR/kWh)	2.99
4	Variable Cost (INR/kWh)	2.99
5	Ramp Up rate(MW/min) for each unit	94
6	Ramp down rate(MW/min) for each unit	114

From the variation of Tehri reservoir level for the year 2018-19 it is seen that 66.67% of the times, the reservoir elevation level is more than 789.0 m and can be used for a maximum generation level of 865MW for 66.67% of times of the year. Similarly for 75% of the times in the year, reservoir level is more than 779 m. and can be used for a generation of 597 MW. Thus 75% of the time in a year this hydropower project can be used for providing ancillary services.

For the year of 2016-17, RRAS despatch instructions are been considered for the calculation[21] and these instructions are been converted for the Tehri Hydropower Project with the help of Linear Interpolation with the energy generation. Tehri Hydropower Project has been designed to generate 2797 million units annually. The rate of ramp up and ramp down for the project is 39% and 38% respectively. Also, the hydropower can generate 10% more than its rated capacity when there is the requirement[23]. So, by considering the Linear interpolation the RRAS despatch instruction for the Tehri Hydropower Project are been given in Table 4 for the different reliability levels that are been obtained from the optimization and annual generation determined by THDC.

Table 4 : Ramping UP & down Revenues for year 2018-19

S. No.	Cases	Apr 2018- March 19	Regulation Up (MU)	Price for Regulation Up (M INR)	Regulation Down (MU)	Price for Regulation Down (M INR)
1	THDC generation (2,797 MU)	Energy Despatch	62.33	373.35	7.57	34.06
		Average energy despatch per day	0.16	0.71	0.02	0.10
2	74% dependability (2,195 MU)	Energy Despatch	48.91	293.00	5.94	26.73
		Average energy despatch per day	0.12	0.56	0.02	0.08
3	68% dependability (3,280 MU)	Energy Despatch	73.09	437.82	8.88	39.94
		Average energy despatch per day	0.18	0.83	0.03	0.12
4	61% dependability (3,910 MU)	Energy Despatch	87.13	521.92	10.58	47.61
		Average energy despatch per day	0.22	0.99	0.03	0.14
5	54% dependability (4,888 MU)	Energy Despatch	108.93	652.47	13.23	59.52
		Average energy despatch per day	0.28	1.24	0.04	0.18

As per the market the average revenue generated from the electricity is INR 3.98 per kWh. Additional revenue generated from ancillary services is provided in table 5.

Table 5 : Revenue from Ancillary Services

% Dependability	Units ramped Up (MU)	Revenue Generated (Million INR)	Per Unit Ramping Cost (INR/kWh)	Units Ramped Down(MU)	Revenue Generated (Million INR)	Per unit Ramping down cost (INR/kWh)
74.36	48.91	293.00	6	5.94	26.73	4.50
67.69	73.09	437.82	6	8.88	39.94	4.50
61.03	87.13	521.92	6	10.58	47.61	4.50
54.36	108.93	652.47	6	13.22	59.52	4.50

6.3 Irrigation and Drinking Water Services

Tehri hydropower projects provide improvement in availability of water for irrigation and drinking water purposes in the states of Delhi and Uttar Pradesh. The water is being used for irrigating an additional area of 2.70 lac hectares of area and stabilisation of 6.04 lac hectares of area with different networks of canals and that are been developed by the Uttar Pradesh state[24]. The division of available additional water 4,000 cusecs (113.26 cumecs) from Tehri multipurpose project in the system[24] is given below:

(a) For drinking water purpose in Delhi and Uttar Pradesh, 500 cusecs of water is released.

(b) To the Eastern Yamuna canal system through parallel to the Deoband Canal,1,100 cusecs of water has been released. It take off from the river Yamuna near at city Faizabad and it irrigates areas in Saharanpur, Muzaffarnagar, Meerut and Ghaziabad.

(c) To the Agra canal systems, 1,100 cusecs of water has been released which is been used to irrigate areas of Mathura and Agra.

(d) To the New Jasrana Canal from Lower Ganga Canal, 150 cusecs of water has been released.

(e) To the Eastern Ganga Canal, 1,000 cusecs of water has been released.

The important crops that are been irrigated in the areas of Uttar Pradesh are sugarcane, wheat, potato, and mustard. The increase in production (tonnes) of different crops for the different canals are used from the literature Arora and Mishra[24]. The prices for the above crops are taken from the Department of Food and Public Distribution for both kharif and rabi seasons and these prices are taken for the year 2018-19. The additional benefits generated for the year 2018-19 due to the water released from Tehri Dam are given in Table 5.

Table 6 : Increase in Annual Benefits from Tehri Dam for Irrigation

S. No.	Canal	Water Release (cumecs)	Increase in Annual benefit due to irrigation (Million / annum)				Total increase in benefits (Million/ annum)
			Sugarcane	Wheat	Potato	Mustard	
1.	EYC	31.15	3,644	744	170	34	4,592
2.	EGC	28.31	4,620	1,020	257	91	5,988
3.	AC	31.15	11	545	330	97	983

Along with this, the Tehri Dam is also providing water for the irrigation and drinking water supplies, the benefits which are been provided by the EGC, EYC and Agra canal systems comes out to be INR 11,564 million per annum. The cost of Green House Gas emission for which the Tehri Hydro Power project is providing clean energy comes out to be INR 4,065 Million per annum.

So by including all the benefits of water management services, the cost of non-energy benefits comes out to be INR 15,629 per annum upon which if we consider it for 2,797 million units of generation, the per unit benefits provided by the Water management services comes out to INR 5.58 per kWh which is most of the times is been considered as hidden benefits.

7. CONCLUSIONS

The study shows that the energy generation is not only the sole purpose of establishing hydropower project, but it can be used for energy management services and water management services. In energy management services, energy generation as well as ancillary services plays a crucial role. With integration of Variable renewable energy, the role of ancillary services is increasing day by day and there is very limited resources in the field of ancillary services. Tehri Multipurpose Project has been used to store water and use that water for generation of electricity, irrigation purposes when there is very less precipitation in the downstream of the areas. It also makes a systematic way of distributing the water for the drinking purposes of more than 20 million peoples of Delhi and Uttar Pradesh. Apart from these benefits, it also acts as barrier to flood and drought, and it also generates clean electricity which is the need of the hour. The following conclusions are drawn from the study.

(a) By using Linear Optimization using Chance Constraint Method, Tehri Multipurpose Project is fulfilling the irrigation demand for more than 70% dependability. So, the revenue generated after selling electricity comes out to be INR 8,741 million per annum.

(b) For the required energy generation, the revenue generated for the ancillary services provided by the Tehri Project comes out to be INR 319.93 million per annum.

(c) After combining energy generation and ancillary services provided by Tehri project, the per unit price comes out to be INR 4.20 per kWh.

(d) Release of water from the hydropower project has been used for fulfilling the needs of drinking water and irrigation purposes and reduction in emission of greenhouse gas etc.

(e) Irrigation and water distribution if combinedly taken for Eastern Yamuna Canal, East Ganga Canal and Agra canal the benefits comes out to be INR 11,564 million and if these been converted into 2,797 million units then the benefits comes out to be INR 4.13 per kWh. Tehri Hydropower Project is also providing clean and green energy and by converting these benefits into monetary terms these comes out to be INR 4,065 million which if been converted into per unit comes out to be INR 1.45 per kWh.

(f) Combining the water management services provided by the Tehri Hydropower Project, the hidden benefits provided by the project comes out to be INR 5.58 per kWh.

(g) Apart from the above calculated values, the services are more important for the welfare of society as well as environment. As it's been known that the environment is degrading day by day, these services provided by the hydropower projects are becoming crucial. This makes multipurpose hydropower projects to be the best available renewable resource of energy.

With the increase of penetration of other renewable energy generation, Hydropower should not only be used for generating base power but it should be used for providing the variation in generation and there should be prices based on fulfilling these variations so the owners can improve their financial records. Ancillary services are new in the Indian Grid system and these services acts to stabilise the grid. Thus, proper valuation methods have to be implemented to monetise these benefits. Moreover, there should also reduction in the closing time for the bidding and more rigorous system should be used to maximise the benefits and revenues. The hydropower projects should not only be decided on the basis of just financial feasibility of the electricity generation but other benefits from it should also be considered like irrigation, supply of drinking water, reduction of GHG emission and many others.

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