Risk Analysis for Operational Stage Small Hydro Power Projects of Uttarakhand: A Stochastic Approach Using Monte Carlo Simulation

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Abstract-In this study valuation of operational phase investment related risks in small hydro power project in Uttarakhand state of India is considered. The foremost emphasis of this work is to examine the importance of studying various risk factors related to investment in operational small hydro power project-which is not a common investment practice performed in this particular area. Because of the stochastic nature of variables that compute NPV (net present value)/IRR (internal rate of return), BCR (Benefit cost ratio) it has some uncertainty which cause risk in investment decision. Such external variables are identified based on literature reviews, expert interviews and field survey as follows: capital cost, operational and maintenance, energy generation, environmental hazards, policy changes, social acceptance, etc. The relative importance of these factors are evaluated stochastically and ranked them accordingly. The greatest advantage of this method is that it has simplicity. When dealing with the risk analysis problems, the prevalence of method has been showed: easier and more useful.

Key words: Risk Assessment; small hydro power projects; Parametric Risks, Monte Carlo Simulation

I. INTRODUCTION

The world is increasingly aware that fundamental changes will be necessary to meet the growing demand for energy, ("(Published in the Gazette of India, Extraordinary, Part-II, and Section 3, Sub-section (ii) MINISTRY OF ENVIRONMENT AND FORESTS New Delhi 14," 2006). There are many possible scenarios about what may emerge in the foreseeable future. The Indian economy to grow at 8.5% per cent, it is imperative for the power sector to grow at 8.1 per cent per annum (Government et al., 2012) India's energy basket has a mix of all the resources available including renewables. India wishes to rise power generation from the renewable energy sources significantly, to power its economy; as any further dependence on fossil fuel is unmanageable((New, 2011)

Renewable energy (RE) sources form a tiny portion (less than 10%) of India's overall energy consumption today. (Popovski, Gnjezda, Niederbacher, Naunov, & Milutinovic, 2000) Small Hydro Power energy constitutes more than 15% of the overall renewables mix. However, contribution from Small Hydro Power plants towards the hydro energy generation in India is much unexploited as most of the hydro energy generated is only through large or medium hydro power projects, (Madlener & Ediger, 2004). From the limited success India has achieved in the renewables story, Hydro power energy has contributed over 20% to the renewable energy mix. (Office, 2011).

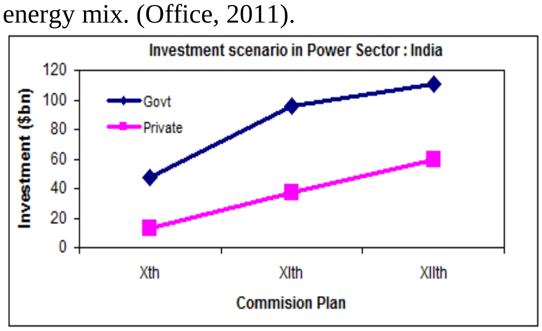


Fig1: Investment scenario in power sector: India

Indian power sector has an installed capacity of 86000 MW. Out of which 25% is hydro power (Chaurasiya, Prasad, & Khare, 2013) and remaining are thermal, nuclear and gas-based projects. Power shortages in our country are estimated as 9%("A Comparative Study of Break Even Point with special

Reference to Dividend Distribution," n.d.) of total energy and 18 % of peak capacity requirements. ("Renewable Energy and Electricity Sustainable Energy Renewable Energy," 2013.)

Investment trend in Hydro power sector based on five year planning commission report figure 1 shows in a constant rate of increase from private sector while the rate become little down after the XIth in the government sector, which reflects the increasing motivation of private partners in power sector business with time. The basic reason of such motivation is attributed to be new thinking in optimization of investment decision with the proper handling of risk/uncertainty of challenges associated with the area of interest (Fleten & Heggedal, 2006.)

The major hydro power electricity generation states of India are Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Arunanchal Pradesh as shown in figure2.Himachal Pradesh installed capacity lies at second position with 22% whereas Uttarakhand is having more which is near to 24%. Uttarakhand is having more scope for harnessing the potential.

The remainder of the paper is organized as follows. Section 2 presents a brief description of the Investors participation in various phases of hydro power projects in Uttarakhand of India, with particular emphasis on small hydropower. Section 3 describes the various investment issues that small hydro power investors face during investment in small hydro power projects Section 4 describes risk analysis in operational stage small hydro power project of uttarakhand. Section 5 assesses the main sources of risk underlying the type of investment under analysis. In section 6 the results of the risk analysis are presented with discussion. Finally, section 7 drawn the main conclusions of the paper and highlights future avenues of research.

II. SMALL HYDRO POWER PROJECT DEVELOPMENT PHASES AND INVESTORS PARTICIPATION

Government has taken a number of steps, beginning with the Electricity Act (2003) and Securitization of State Electricity Board (SEB) dues to reform the power sector and to attract private investments. In addition, Government has taken a number of actions to inspire new dimensions addition by the private sector.

In Small Hydro Power projects the investors wants to invest in various stages of power plants that is shown in the Figure 3. The major four stages in Small Hydro Power plants are described the initial stage where the power plants are under pre construction stage when the plant is proposed after detailed prefeasibility study by the investors in the form of detailed project report (DPR). Once that DPR got approved the plant construction will begin including various phases as clearances, construction scheduling, budgeting, financing i.e. after construction plant comes to operational phase which is the longest phase of power generation. Due to longevity of phase it passes through maximum uncertainties. Running the plant for operational phase for almost 35-40 years wear and tear starts in the power project that increase the operational and maintenance cost.so as safety and technological advancement is another concern investor rethink about renovation and modernization of the existing plant with latest practices. The risk is varying in different phases in terms of severity and probability. This paper focuses on operational stage which as discussed earlier faces more risk and uncertainties due to longevity.

III.INVESTMENT ISSUES IN SMALL HYDRO POWER PROJECTS

The private sector has been discover it enormously challenging to directing investment into new hydropower projects due to issues that can compromise an otherwise functional project, such as social and environmental opposition, unwanted project risks, large upfront costs, long lead times and lower returns on investments (Nandy & Bhattacharya, 2012). More importantly, in attempting to privatize hydropower electricity, the public sector looks to passing on the risks involved in construction, operation and maintenance, to the private sector.

Every decision for a small hydropower project is made with uncertainty. Ujvnl does investment decision for small hydro power projects using tariff analysis as per the guidelines of UERC. If tariff comes more than the estimated one unit electricity production cost than project considered as viable. It was observed in SHP's that estimated cost for electricity production comes less than actual cost. There are many uncertainties are existing those are neglected at the time of DPR preparation, which creates cost overrun. As in one power plant of Uttarakhand shows minute changes in investment cost, River Head, River Discharge, maintenance cost will impact electricity production cost showed in figure 3.

Table 1: General Information for Pathri and Mohammadpur Small hydroelectric power projects

Variables	Mohammadpur SHP	Pathri SHP
Capital cost	6435.49 Rs in Lacs	9282.42 Rs in Lacs
Break down of Cost	4 36 2	15 3 47%
O & M cost	0.134 Rs/KWH	0.15 Rs/KWH
Installed Capacity	9.3 Mw	20.4 Mw
Average Capacity	4.62 MW	10.3 Mw
Average Energy	40.44 MU	89.91 MU
Deterioration Rate	1%	1%
Remaining Life	15 Years	15 Years
Present Per Unit Rate	1.2 Rs/KWH	1.05 Rs/KWH
Discount rate	10%	10%

Globally the small hydro power projects consider many factors that create a possibility of cost overrun. As (Wiemann, 2011) shows if running hour per hour is increased how electricity production cost is also increased. Similarly there are a lot of factors which create risk for small hydro power project. small hydropower plant investment involves risks due to a number of factors such as technical, market, financial, environmental, socio-economic, policies and various subcategories lie under these. These factors have influences on cost and revenue.

Investors wishing to invest in renewable energy must be aware of all the risks to consider their effect on profitability. The investors benefit will be increased if more and more risks were identified in the beginning and if truly assessed so risk management would work well.

(Lundmark & Pettersson, (2002.); (Harrison, Whittington, Gundry, & Management, 2004.)), (Kucukali, 2011) and Chirikutsi (2006) explain major investment risks in small hydropower sector as price, market, climate, technology, regulatory, environmental, socio-economic, interest rate, (Hosseini, Forouzbakhsh, & Rahimpoor, 2005) who used different investment decision making approaches to quantify and asses the risk in small hydropower project. (Zhang et al., 2010) and (Firestone, Fenner-crisp, Chang, & Callahan, 1997) used various techniques, like deterministic, probabilistic, stochastic and strategic for risk assessment in small hydropower project (Gains et al., 2002) applied Monte Carlo simulation as a stochastic approach in for parametric risk analysis, he found as one of the best methods. Within the context this paper intends to outline the major risk assessment involved in the operation stage of small-scale hydropower projects of uttarakhand.

IV. RISK ASSESSMENT PROCESS

Risk analysis involves both risk identification and risk Assessment.

4.1 Risk identification

Risk identification is the process of recognizing the hazards (initiating events) to which the Small Hydro Power project is exposed, potential project failure modes, and the resulting adverse consequences. The twenty five risk factors were identified based on the expert interviews and literature review and categorize them into quantitative and qualitative/subjective factor. The parametric risk factors are considered in this study. The major risk factors as per expert opinion and literature review for small hydro power projects of uttarakhand are found as climate, regulatory, policy, socio economic factors. The uttarakhand rehabilitation problem for constructing dam for power production is not supported by local communities and high court as it creates environmental imbalances. The policy related with hydro power project keep on revising with market and political environment revisions. Market uncertainty changes the price of electricity so as political environment changes the price of electricity,

tax rate, inflation consequently profit of investors are impacted. The other risk factor that affects the investors is fluctuating interest rate and tax rate
Hydropower projects face many risks such as market risk, credit risk, simple construction and development risk, political risk, legal risk, force majeure risk, etc. The assessment of these risks and investor decision making measures will be discussed in the paper.

4.2 Risk Analysis For Parametric Risk Factors

Risk estimation consists of determining existing uncertainty response and outcome probabilities, and the consequences of various cost overruns. No-cost overrun scenarios are considered so that incremental consequences can be estimated as the difference between the consequences estimated with cost overrun and without cost overrun scenarios. Probability and consequence estimates are then input to the risk model. Consequences are a function of many factors including, the nature and extent of the breach, the extent and character of the operations & Maintenance cost, capital cost, the season of the year, the warning time, and the effectiveness of evacuation and emergency action plans.

Table 2: Risk Analysis criteria (Input Parameters) and their probability Density Functions (PDF)

	Pathri		**Mohammadpur**	
Variable	**Distribution Type**	**Parameters**	**Distribution Type**	**Parameters**
Average Capacity	**Normal**	**Mean-16.6,S.D-2.6**	**Normal**	**Mean-17.7,S.D-1.77**
Average Energy(Generation)	**Lognormal**	**Mean-56.60; S.D.-7.71**	**Lognormal**	**Mean-155.6; S.D.-1.57**
Energy Price	**Uniform**	**minimum-1.2; maximum-2.9**	**Uniform**	**minimum-1.2; maximum-2.9**
Capital cost	**Triangular**	**Min-5791.59; Likeliest-6435.49; Maximum-7579.36**	**Triangular**	**Min-8354.18; Likeliest-9282.12; Maximum-10210.66**
Discount Rate	**Logistics**	**Mean-12%; scale-2**	**Logistics**	**Mean-10%; scale-1**
Operation &Maintenance cost	**Lognormal**	**Mean-.15; SD-0.02**	**Lognormal**	**Mean-.15; SD-0.02**
Capital cost Break Up Ist Year	**Triangular**	**Min-37%; Most Likely-41%,Max-45%**	**Triangular**	**Min-14%; Most Likely-15%,Max-17%**
Capital cost Break Up 2nd Year	**Triangular**	**Min-32%; Most Likely-36%,Max-40%**	**Triangular**	**Min-35%; Most Likely-38%,Max-42%**
Capital cost Break Up 3rd Year	**Triangular**	**Min-21%; Most Likely-23%,Max-25%**	**Triangular**	**Min-42%; Most Likely-47%,Max-52%**

For quantitative analysis we used statistical method, selecting Monte Carlo Simulation technique (MCS) based on available historical data from two different projects in

Uttarakhand SHP. We have analysed quantitative risk in two different projects in operational phase, viz. Pathri and

Mohammadpur which are located in uttarakhand area and their major cost components are shown in table 1.these two projects are compared in the result section.

Risk reduction alternatives are developed and analysed in a similar manner to the existing dam with selected inputs, such as system response probabilities, changed to represent the improved performance estimated for each alternative.

V. RESULT

In this section Monte Carlo simulation result is discussed for both Pathri and Mohammadpur hydroelectric power project.

5.1 Sensitivity Analysis Of Major Risk Factor

The sensitivity analysis on project NPV with reference to increase in electricity price, increase in capital cost and decrease in cost of capital is shown in Fig 4 (a),(b) & (c) . The fig 4 (a) clearly shows as with the increase in electricity price NPV is decreasing and at one specific electricity price the NPV becomes zero and again it increased negatively. After checking the gradient of the NPV corresponding to electricity price the slope is very significant as it is increasing from 27% to 37% than again increase till 85% that is quite significant slopes are visible. Fig b shows Capital cost increment with respect to NPV where increments in the slope of NPV from 51% to 95% which is quite significant. Fig c shows the sensitivity on NPV of decrease in cost of capital where changes from 23% to 96% slope. The above three parameters capital cost, electricity price and cost of capital impact NPV and these are very sensitive parameters for investors.

Sensitivity Analysis of NPV against Fig 4 (a) capital cost; (b) Price; (c) Cost of Capital

5.2 Determination Of Certainty For Parametric Risk Factors

For determination of certainty of parametric risk factors will be assessed using case study of operational stage SHP, pathri. In pathri the parametric risk factors are considered as interest rate, average Energy (generation) , capital cost, operation & maintenance cost, breakdown cost, price of electricity per unit for last 19 years is considered. The probability density functions (PDF) of each risk parameter is created. All parametric variables whose pdf is created are shown in table1. The Monte Carlo simulation (MCS) runs including above mentioned PDF for financial indicators NPV, IRR & BCR shown in figure 5.1 & 5.2 (a), (b) & (c) for pathri and mohammadpur respectively. The simulation shows the certainty of the estimated NPV, IRR & BCR in table 3.

The certainty on estimated NPV is 25.39% & 61.54%, IRR is 24.62%& 62.04% & BCR25.33% & 62.07% for pathri and mohammadpur projects respectively. The low certainty indicates that estimated financial indicator was not evaluated as risk free estimation in traditional practice; it was purely based on assumption of investment manager.

Table3: Financial indicator Outcome for Pathri & Mohammadpur Hydro Electric power projects Without and with Risk consideration

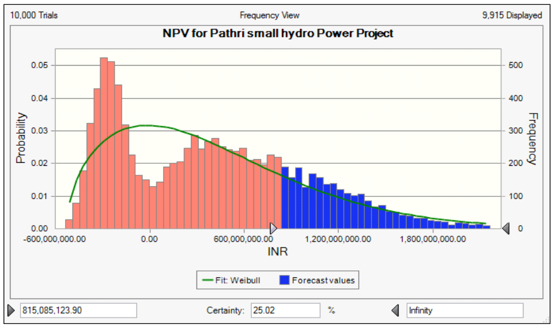
	Pathri small hydro Electric Power Project			**Mohammadpur Hydro Electric Power project**		
Financial Indicators	**Estimated Values**	**without considering risk Certainty**	**With Risk Consideration certainty(Using MCS)**	**Estimated Values**	**without considering risk Certainty**	**With Risk Consideration certainty(Using MCS)**
NPV	**815085124**	**100%**	**25.39%**	**75898097**	**100%**	**61.54%**
IRR	**18.83%**	**100%**	**24.62%**	**11.83%**	**100%**	**62.04%**
BCR	**2.15**	**100%**	**25.33%**	**1.15**	**100%**	**62.07%**

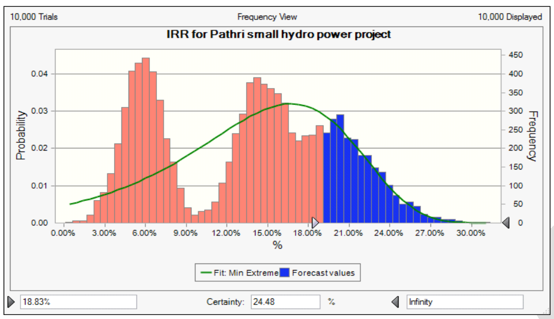
The differences between estimated financial indicators as on the traditional practice (DPR document) and with risk adjustment using Monte Carlo Simulation (present study) is shown in table no 2. Our sensitivity results on financial indicator shows the most influential factor comes out to be capital cost, interest rate, average capacity, operation & maintenance cost (see Figure6.1& 6.2 (a),(b) & (c). Table 4 shows significant cost overrun due to not considering risk parameters while estimating financial indicators. The MCS generates uncertainty on NPV/IRR/BCR values due to specific investment cost (total investment cost of the project divided by the installed capacity) of river-type hydropower plant in uttarakhand in the range of 2.7 Rs/kW that was assumed but actually it was varies from 1.7 to 3.9 Rs.

Table 4: Cost Overrun in operational stage small hydroelectric power project

Description	**Estimated Cost(Lacs)**	**Actual Cost(Lacs)**	**Rate of Increase**	**Share of total Cost**
Turbine and generator(Electromechanical equipment's)	**397**	**445.434**	**12.20%**	**3.56%**
Transformers & Electricals(Electromechanical Equipment)	**4816.09548**	**6900.5574**	**43.28%**	**55.17%**
Hydro Mechanical Works (equipment)	**329.6**	**421.68953**	**27.94%**	**3.37%**
Civil Works(Design Changes)	**195**	**219.102**	**12.36%**	**1.75%**
IDC	**1200.13**	**1747.1493**	**45.58%**	**13.97%**
Grid Connection	**2344.59452**	**2774.8276**	**18.35%**	**22.18%**

It is also reported that the civil works account for 60-70% of capital cost based on assumptions actually there is triangular distribution found in capital cost. Each hydropower project is site specific that can explain the wide range of investment costs. The main factors which can lead to capital cost breakup which was not considered creates cost overrun. The investment cost a





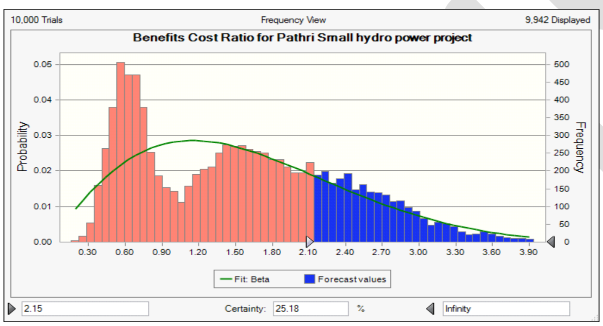
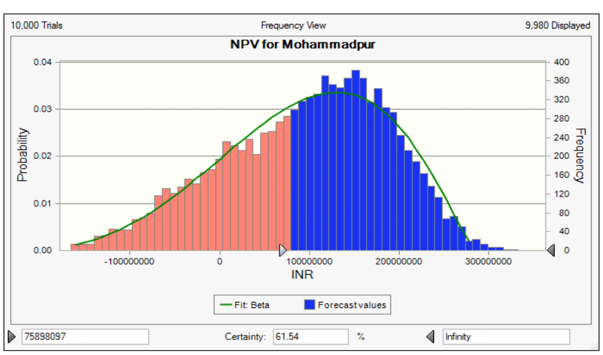
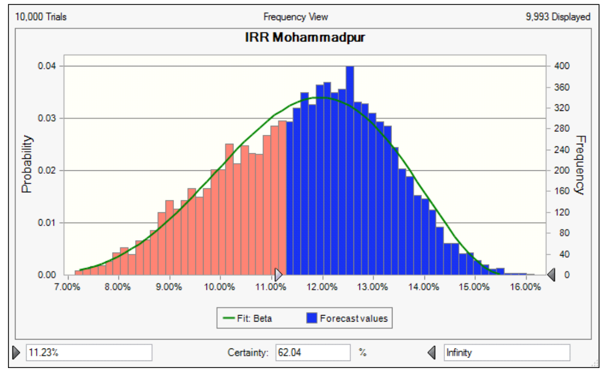


Fig 5.1: (a),(b) & (c) NPV, IRR & BCR Estimation using Monte Carlo simulation on Pathri Hydro Power project





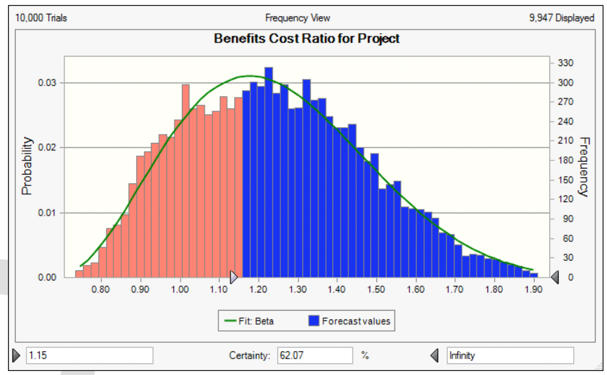


Fig 5.2: (a),(b) & (c) NPV, IRR & BCR Estimation using Monte Carlo simulation on Mohammadpur Hydro Power project

hydropower plant can be classified as follows: Turbine and generator(Electromechanical equipment's); Transformers & Electricals(Electromechanical Equipment); Hydro Mechanical Works (equipment); Civil Works(Design Charges); IDC(interest During Construction); Grid Connection in Table 3 that shows the assumed and actual increase in the cost and increase in cost. For pathri and mohammadpur the certainity without and with risk estimation comes out to be different reason behind this is

VI.DISCUSSION

Sensitivity analysis is a tool for judging one risk parameter impact on outcome, as mentioned in paragraph 5.1 the impact of capital cost, price of electricity and cost of capital on NPV is visible but not all the risk factors are considered all together.one major thing associated with sensitivity analysis is that it is not treating any non-parametric variables MCS which is a stochastic tool and it assesses the impact of all the parametric risk factors together on outcome as NPV, IRR & PI. All the parameters that are significant to the outcome of the project thus the variables that have a negative impact on the NPV and IRR. Still, this kind of analysis is taking in consideration a change of only one variable, while taking all the other variables constant and cannot compute the change of some variables at a time. Also this analysis is ignoring any possible correlation between several risky variables.

VII. CONCLUSION

Risks associated with operational stage SHP investment are identified. These risk items serve as a checklist that cover possible risks associated with SHP investments in operational phase. Risk

managers or investment decision makers can be informed and be able to recognize the risks associated with SHP investments.

Investment decision makers can predict the overall risk of the project investment entire as well as phase wise before start the investment. An overall risk index can be used as early indicators of project problems or potential difficulties. Evaluators can keep track to evaluate the current risk level with the progress of investments.

Moreover, it was assumed that if one project in the same phase if it is more risky so all the projects have similar risk. This myth is demolished with the help of this paper where in the same stage two power projects in same geographical area contains different certainties reason being factors considered for risk assessment relative importance by individual decision makers and experts could be widely different.

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REFERENCES

[1]. (Published in the Gazette of India, Extraordinary, Part-II, and Section 3, Sub-section (ii) MINISTRY OF ENVIRONMENT AND FORESTS New Delhi 14. (2006), (ii), 1–43.
[2]. A Comparative Study of Break Even Point with special Reference to Dividend Distribution. (n.d.).
[3]. Chaurasiya, P. K., Prasad, V., & Khare, R. (2013). Scenario And Risk Of Hydro Power Projects In India, *5*(2), 1068–1075.
[4]. Firestone, M., Fenner-crisp, P., Chang, S., & Callahan, M. (1997). Guiding Principles for Monte Carlo Analysis, (March).
[5]. Fleten, S., & Heggedal, A. M. (n.d.). C LIMATE POLICY UNCERTAINTY AND INVESTMENT BEHAVIOR : E VIDENCE FROM SMALL.
[6]. Gains, A. T. H. E., Of, L., Non, A. G., Structural, L., Belgian, U., & Data, P. (2002). NATIONAL BANK OF BELGIUM WORKING PAPERS - RESEARCH SERIES FINANCE , UNCERTAINTY AND INVESTMENT : ASSESSING THE GAINS AND LOSSES OF A GENERALIZED NON LINEAR STRUCTURAL APPROACH This paper is part of the research program on " New views on firms ' investment, (26).
[7]. Government, T., Plan, N., Plan, T., Report, W. G., Commission, P., Authority, C. E., … Bill, E. (2001). Power 8.2.1.
[8]. Harrison, G. P., Whittington, H. W., Gundry, S. W., & Management, R. (n.d.). CLIMATE CHANGE IMPACTS ON HYDROELECTRIC POWER, (1).
[9]. Hosseini, S. M. H., Forouzbakhsh, F., & Rahimpoor, M. (2005). Determination of the optimal installation capacity of small hydro-power plants through the use of technical, economic and reliability indices. *Energy Policy*, *33*(15), 1948–1956. doi:10.1016/j.enpol.2004.03.007
[10]. Kucukali, S. (2011). Risk assessment of river-type hydropower plants using fuzzy logic approach. *Energy Policy*, *39*(10), 6683–6688. doi:10.1016/j.enpol.2011.06.067
[11]. Lundmark, R., & Pettersson, F. (2007). Investment Decisions and Uncertainty in the Power Generation Sector, 1–14.
[12]. Madlener, R., & Ediger, V. (2004). Modeling Technology Adoption as an Irreversible Investment Under Uncertainty: The Case of the Turkish Electricity Supply Industry, (30).
[13]. Nandy, M., & Bhattacharya, S. (2012). Energy Issues in India and South Africa.
[14]. New, M. O. F. (2011). STRATEGIC PLAN FOR NEW AND RENEWABLE ENERGY SECTOR GOVERNMENT OF INDIA, (February).
[15]. Office, C. S. (2011). Energy statistics 2011.
[16]. Popovski, K., Gnjezda, G., Niederbacher, P., Naunov, J., & Milutinovic, I. (2000). O p t i m i z a t i o n of the g e o t h e r m a l d i s t r i c t heat- ing system "geoterma" - kocani, macedonia, 310–313.
[17]. Renewable Energy and Electricity Sustainable Energy Renewable Energy. (n.d.).
[18]. Wiemann, P. (2011). RISK MANAGEMENT AND RESOLUTION STRATEGIES FOR ESTABLISHED AND NOVEL TECHNOLOGIES IN THE LOW HEAD ,, (1).
[19]. Zhang, X., Yang, M., Xue, Y., Liang, H., Boulton, W. R., Working, T., … Mwaipopo, O. U. (2010). No Title. *International Journal of Production Research*, *25*(1), 1–11. doi:10.1080/00207540903117907