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Emerging DSS Tools for RETs: A Case Study

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Abstract: This paper gives brief introduction of accessible Decision Support System/Software (DSS) tools to plan and develop initial report of small hydropower site (SHPs) for making decision to go further process useful in western Himalayan region. The software tools available for analysis, varies from simple estimation to dedicated special design software. The evaluation of latest SHP sites for planning and development may involve huge amount of total project cost. Multidimensional assessment at pre-feasibility stage might be administered by experienced and highly expertise during this field or professional's for an equivalent. To the most effective of the author's knowledge use of such DSS tools for feasibility analysis of RETs project in Indian scenario gives low cost, minimum time and effort estimation for higher cognitive process.

Keywords: RETs; SHP; Feasibility Study; Small Hydropower; Decision Support System.

I. Introduction

In India, the total potential for renewable electrical energy generation is estimated 10,01,132MW, which includes 6,49,342 MW (i.e. 64.86%) solar potential, 3,02,251 MW (i.e. 30.19%) wind energy potential at 100m height, 21,134 MW (i.e. 2%) SHP (small-hydro power) potential and 18,601 MW (i.e. 1.86%) biomass power as on 31/07/2017 [25]. The total identified small hydroelectric capacity was reported as 21,134 MW out of which only 4379.86 MW i.e. 20.72% is installed grid interactive small hydropower as on 31/03/2017 [25].

Small hydroelectric sites (i.e. <25MW) are further ecological, economical than traditional or large hydroelectric plants. SHP requires low head or minimum flow rather than traditional hydroelectric plants. Storage dam or reservoir is not needed for SHP, Environment and social footprints of SHP are negligible [1, 2]. Assessment of new SHP site covers a large part of total project cost. DSS tools around the world are readily available for making an initial rough economic estimate and feasibility of a Small Hydropower Project (SHP) before going through accurate site assessment. Computer based software tools gives from simple estimates to quite details reports. Still, an actual analysis of feasible potential requires actual sites surveying and their electric potential calculation.

The main goal is to check applicability of available computer based programs and its features (e.g. –RETScreen, Matlab, Homer energy etc.) dedicated for small hydroelectric potential identification and pre-feasibility studies.

II. Tools for SHP Assessment

Every hydropower site is unique and different from other. Computer based appli-cation programs for RETs assessment can be available with GIS or without GIS fea-ture. Most of the software application programs were developed 2-3 decades before, and some of them (for instance, Homer Energy, and Matlab, RETScreen®) have been continuously improved. Internationally recognized some tools briefly discussed be-low:

i.HydrA

HydrA a computer based small application program developed by 'European Atlas, United kingdom' for identification of Small hydroelectric resources, This was programmed for quick identify suitable turbine for potential power generation and estimates whole small hydroelectric potential for given location[8].

ii.IMP 5.0

IMP 5.0 (Integrated Method for Power Analysis) developed by Natural Resources, Canada, is a convenient application for estimating and evaluating SHPs [16, 22]. By using IMP 5.0(with relevant meteorological and topographical data), user can measure all measures of an entered hydro site. IMP gives report on Flood Frequency Model, Hydroelectric Power Simulation Model, Watershed Model and Fish Habitat impact.

iii.Peach

PEACH developed by ISL, France, is a dedicated software for initial investigation of hydro sites. This tool includes engineering technical methods, widely applied at introductory level, and also gives economic stability estimation and financial data for hydroelectric project [16, 18]. It may includes following steps: definition of site data, creation of proposed project, design of project, design of plant, financial and economic report etc. The outcomes includes:

- Definition of project and design parameter

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- Construction estimates
- Quantities required
- Cash flow and power
- Financial and economical analysis reports

iv.HES

HES (Hydropower Evaluation Software) developed by 'Dept. of Energy, IEEL, USA', especially for United States of America, enables user to think about environmental, legal and institutional constraints[21, 24]. This application makes use of environmental characteristics and federal land law and legal data to make a project sustainability factor report.

v.Smart Mini IDRO

Smart Mini IDRO developed by ERSE SpA, Italy is based on MS Excel application. This application primary used for introductory study of SHP. This application uses flow duration curve for electrical energy potential calculation and suggested type of turbine for potential energy generation. Economical estimation is also generated [8].

vi.HydroHelp

HydroHelp 1.6 developed by OEL HydroSys Inc, Canada under the guidance of James L. Gordon, includes six excel based application series that gives opportunity to professionals to compute detailed initial cost estimation for hydroelectric plant sites [16, 20]. The software doesn't gives hydrology characterstics and financial analysis:

- HydroHelp 1.6 for Selection of Turbine
- HydroHelp 2.6 Francis turbines application.
- HydroHelp 3.6 Impulse turbines application.
- HydroHelp 4.6 Kaplan turbines application.
- HydroHelp 5.4 underground pump-turbines
- HydroHelp 6.4 underground Francis turbines

vii.iHOGA

University of Zaragoza, Spain developed a C++ application named Improved Hybrid Optimization by Genetic Algorithms (iHOGA) program for optimization and simulation of Hybrid RETs (Renewable Energy Technologiess) including SHP for generation of electrical power of any size [8, 21].

viii.RETScreen

RETScreen is a user-friendly Excel-based freebie application developed by Natural Resources, Canada. This renewable energy technology DSS Software is aimed to make easier viability and pre-feasibility analysis of renewable energy technologies. RETScreen gives facility to user to make easier analysis and estimation of potential available before start project development of various clean energy technology and hydro energy projects. This module includes seven reports, first have to complete Energy Model, Hydrology data & Load and equipment details, then cost analysis performed and financial summary of project is generated with payback period and cash flow, income etc. and then GHG emission analysis is a comparison or saving of green house gases emission reduction via traditional large electric project and then sensitivity analysis of project provide estimate of prime financial keys and factors. Small hydro, Mini hydro, and Micro hydro are three categories which is used by application to classified and evaluate small hydroelectric projects [23].

ix.Green Kenue

Green Kenue is a GIS enabled advance application developed by National Research Council, Canada for hydrology modeling. This application makes user capable for modeling of hydro projects. Green Kenue provides user interface for single and shared interface and appearance for more rigorous hydrologic estimates required for designing of SHP sites [16].

x.Homer Energy

Hybrid Optimization Model for Multiple Energy Resources (Homer) is a modeling application assembled by 'National Renewable Energy Laboratory, USA', for providing a overview of RETs design and make it easy comparison between energy generation across a broad field of RETs [16, 20]. HOMER provides capability to collation many different technologies design alternatives based on distinct technical and reasonable virtues selected by the user.

xi.MATLAB

MATLAB **(**Matrix Laboratory) is a multi-standard numerical computing environment written in C/C++ and Java language developed by MathWorks, USA. MATLAB allows key users to matrix manipulations, data and function plotting, algorithms implementation, establishment and **s**olution of a large optimization problem, data fitting, and parameter estimation. Saving in time via tiny version and enables user to distinguesh an effective solution that could be normally practice for the major scale problem [20]. Quadratic function and derivative programming with Nonlinear optimization are 3 techniques for determining a suitable scheme for optimal performance of a hydropower site. DSS tools with its features for RETs evaluation which are applicable internationally are categories below in Table I.

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TABLE I. List of DSS tool with its main features [1].

Computer Applications				Main Features			
Name	Manufacturer	Energy and power	Costing	Hydrology	Economic Estimation	Introductory design	Hybrid Simulation
HydrA	European Atlas, UK	*	-	*	-	*	-
IMP	NR, Canada	*	-	*	-	-	-
PEACH	ISL , France	*	*	*	*	*	-
HES	DoE, USA	-	-	*	-	-	-
Hydro-help	OEL HydroSys, Canada	*	*	*	*	*	-
RETScreen	NR, Canada	*	*	*	*	-	-
Green Kenue	NRC, Canada	*	-	*	-	-	-
Smart Mini IRDO	ERSE SpA, Italy	*	*	*	*	-	-
Homer	NREL, USA	*	-	*	*	-	*
Matlab	Mathworks,USA	*	-	*	-	-	*

III. MATERIAL AND METHODS

RETScreen renewable energy analysis software application is a DSS tool manufactured to assist the experts and key decision makers in preparing the RETs feasibility elements such as energy potential availability at the project location, hardware performance, initial estimate overview, total project expenditure costs, income through energy generation, environmental properties, GHG emission reduction etc. NASA's Satellites driven meteorological data includes with feature to enter ground-based meteorological data also makes RETScreen application can be used worldwide. This application software is used in the feasibility analysis of 12MW capacity SHP project of HPSEBL, Baner Powerhouse (3x4 MW=12MW) is a run-of-river scheme in district Kangra of Himachal Pradesh, India was selected to perform detail analysis through application summarized in this paper[4].

IV. RESULT AND DISCUSSIONS

The selected project site is located on the left banks of Baner khad, a tributary of the Beas river, which aries from the southern slopes of the Dhauladhar range of the Great Himalayas at an altitude of about 4678m. Baner Khad is a snow fed rivulet. The rivulet has a natural bowl like pond about 2 to 2.5m in depth with a free water surface area of 230 sq. m at normal pond level of 1728.71m in the khad. Baner Power House Located on the Left bank of "BANER KHAD" at Vill Jia, Teh Palampur, Distt Kangra, Himachal Pradesh. The geographical co-ordinates of the baner project site are as under: Latitude- 760 28'10"E; Longitude- 320 10'7"N; Altitude- 1388.03m.

FIGURE 1: Location of Baner SHP on Google Maps.

The relevance and suitability of this tiny software for the selected SHP viability study will also evidence of its potential to perform in easy way feasibility analysis in western himalayan region, with different design options and initial financing requirement with different economic narratives. RETScreen small hydroelectric project provides six worksheets as: Start Sheet, Energy Modeling, Cost Estimation, Financial Analysis,GHG Emission Reduction (Optional), Sensitivity and Risk Analysis (Optional).

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A. Start Worksheet

In the start worksheet of the RETScreen hydroelectic application for Baner Small Hydropower Project required information fill by user is presented in figure 2. Central grid connected, isolated or off-grid connection are three grid type to select. Since establishment of the Baner SHP electricity generated is given to the HPSEB Ltd, hence central grid connected obtion is selected. There are two types of analysis type. Second method requires more detailed information than first method, because sufficient amount of site date is available so it is preferable to use second method. If first method is selected that cost estimate, emission reduction, financial and risk analyses not calculated. To carried out this study for Baner SHP, second method was selected. Heating value is vital measure to exactly calculate total energy released when fuel is completely burned, but in this case hydropower projects, this value is required to carried out emission reduction compare to coal/fuel. Here, Lower heating value (LHV) is selected. Show setting selection displays the language, currency and unit used.

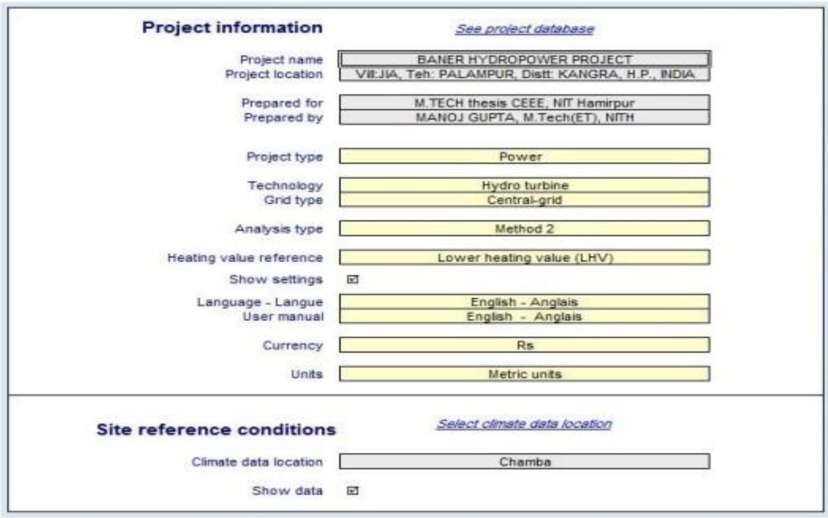

FIGURE II: RETScreen Start worksheet. (Prepared for Baner SHP Analysis).

B. Energy Model sheet

Energy model required input from user and selection between methods of analysis. If first method is chosen, a simplified analysis supported by hydro turbine capacity and power factor is performed. If second method is chosen, a detailed analysis calculation with the help of hydrology and hardware parameters data. For this analysis 'Baner SHP project', second method is chosen. The second method depends on the flow duration curve or hydrology data for the project site river. Availability of hydrology data at specific site, thus user-defined should be chosen. Firm flow is entered 100% available because RETScreen suggests firm flow percentage between 90% to 100%. Turbine efficiency is available so entered manually.

However, RETScreen application has included standard efficiency curves for generally available turbine types with the efficiency modification adjustment, these efficiency curves are often adjusted and may be utilized in the sensitivity analysis. For Baner SHP, standard efficiency curves of Pelton turbines inbuilt with RETScreen application is utilized without adjustment (fig. 4).

The another part of RETScreen energy model for the application of Baner SHP, RETScreen utilized chosen data together with the gross head available, system losses and turbine properties to calculate power potential and electricity generated. RETScreen recommends a value should be 5 % for most hydroelectric plants for maximum hydraulic errors. Electricity export rate should be required in the energy model, which is used to calculate the income from electricity sale by the software. Here we have considered Rs1.65 /kWh, i.e. Rs.1650/MWh (average value taken from HPSEBL, 2001).

C. Cost Analysis

RETScreen offers cost estimations of two types; a detailed cost estimation method and hydro formula estimation method. The user requires to enter the number of units and cost of unit for particular hardware. This method has two other sub methods included. The user can choose one of them considering the detail value available for cost estimation.

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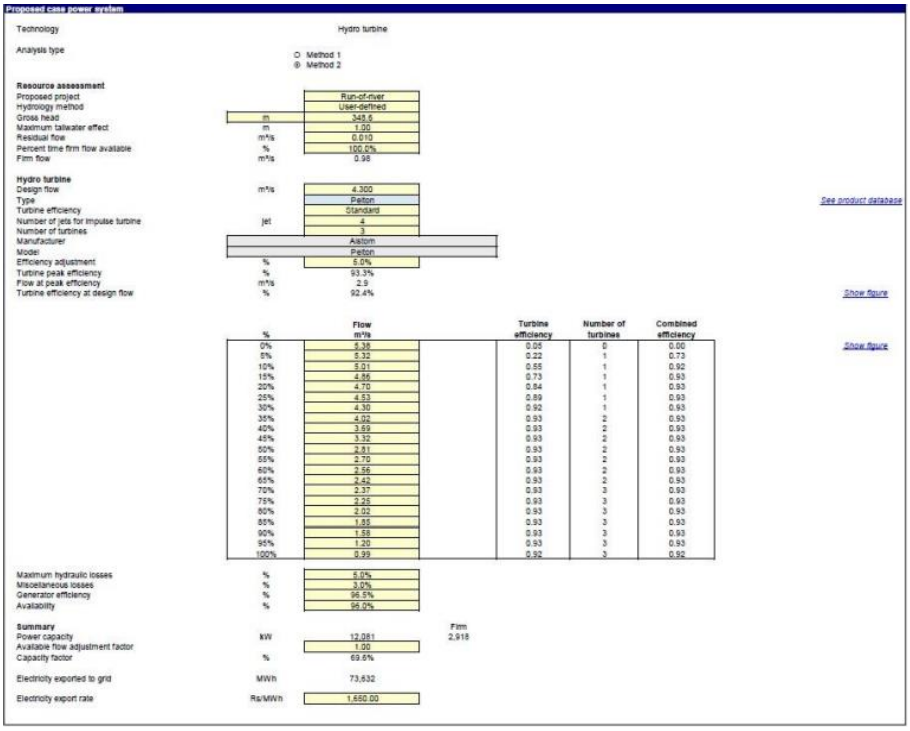


Proposed case power system

Technology		Hydro turbine
Analysis type		○ Method 1 ◉ Method 2
Resource assessment		
Proposed project		Run-of-river
Hydrology method		User-defined
Gross head	m	348.6
Maximum tailwater effect	m	1.00
Residual flow	m³/s	0.010
Percent time firm flow available	%	100.0%
Firm flow	m³/s	0.98
Hydro turbine		
Design flow	m³/s	4.300
Type		Pelton
Turbine efficiency		Standard
Number of jets for impulse turbine	jet	4
Number of turbines		3
Manufacturer		Alstom
Model		Pelton
Efficiency adjustment	%	5.0%
Turbine peak efficiency	%	93.3%
Flow at peak efficiency	m³/s	2.9
Turbine efficiency at design flow	%	92.4%

See product database

Show figure

%	Flow m³/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	5.38	0.05	0	0.00
5%	5.32	0.22	1	0.73
10%	5.01	0.55	1	0.92
15%	4.86	0.73	1	0.93
20%	4.70	0.84	1	0.93
25%	4.53	0.89	1	0.93
30%	4.30	0.92	1	0.93
35%	4.02	0.93	2	0.93
40%	3.69	0.93	2	0.93
45%	3.32	0.93	2	0.93
50%	2.81	0.93	2	0.93
55%	2.70	0.93	2	0.93
60%	2.56	0.93	2	0.93
65%	2.42	0.93	2	0.93
70%	2.37	0.93	3	0.93
75%	2.25	0.93	3	0.93
80%	2.02	0.93	3	0.93
85%	1.85	0.93	3	0.93
90%	1.58	0.93	3	0.93
95%	1.20	0.93	3	0.93
100%	0.99	0.92	3	0.92

Show figure

Maximum hydraulic losses	%	5.0%	
Miscellaneous losses	%	3.0%	
Generator efficiency	%	96.5%	
Availability	%	96.0%	
Summary			Firm
Power capacity	kW	12,081	2,918
Available flow adjustment factor		1.00	
Capacity factor	%	69.6%	
Electricity exported to grid	MWh	73,632	
Electricity export rate	Rs/MWh	1,650.00	

FIGURE III: Energy Model Worksheet (Prepared for Baner SHP Analysis).

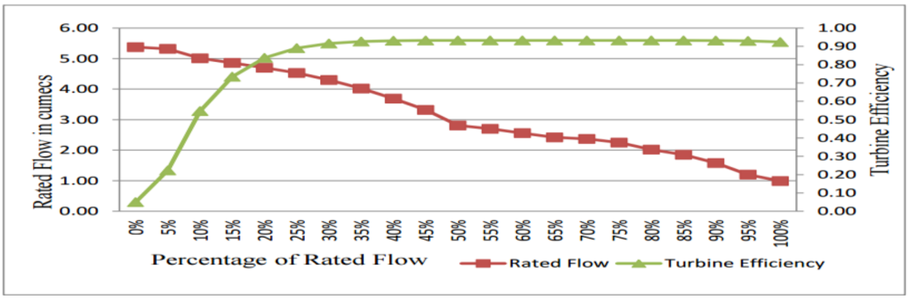
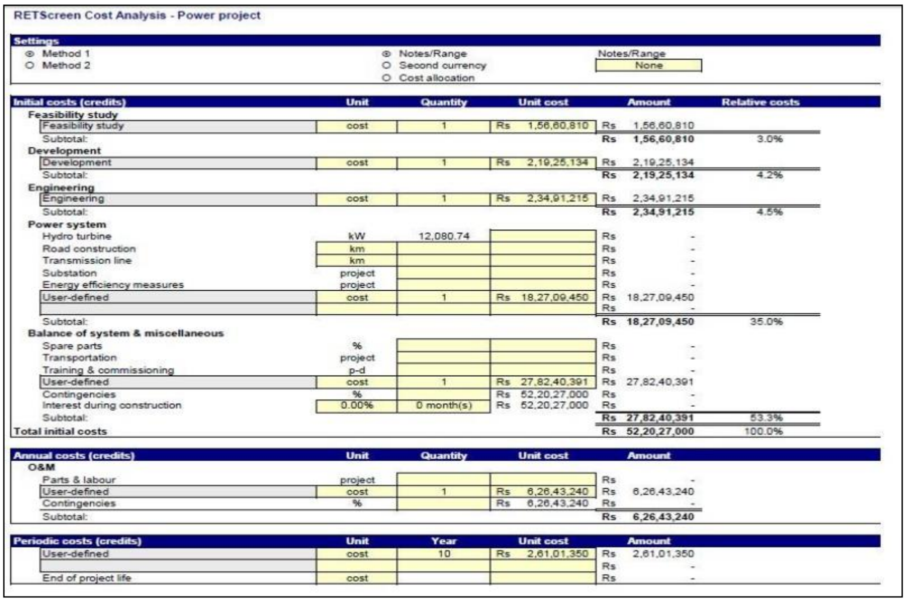


FIGURE IV: Turbine Efficiency Curve w.r.t Flow Duration Curve (Prepared for Baner SHP Analysis).



RETScreen Cost Analysis - Power project

Settings

◉ Method 1 ○ Method 2 | ◉ Notes/Range ○ Second currency ○ Cost allocation | Notes/Range: None

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost	1	Rs 1,56,60,810	Rs 1,56,60,810	
Subtotal:				**Rs 1,56,60,810**	3.0%
Development					
Development	cost	1	Rs 2,19,25,134	Rs 2,19,25,134	
Subtotal:				**Rs 2,19,25,134**	4.2%
Engineering					
Engineering	cost	1	Rs 2,34,91,215	Rs 2,34,91,215	
Subtotal:				**Rs 2,34,91,215**	4.5%
Power system					
Hydro turbine	kW	12,080.74		Rs -	
Road construction	km			Rs -	
Transmission line	km			Rs -	
Substation	project			Rs -	
Energy efficiency measures	project			Rs -	
User-defined	cost	1	Rs 18,27,09,450	Rs 18,27,09,450	
				Rs -	
Subtotal:				**Rs 18,27,09,450**	35.0%
Balance of system & miscellaneous					
Spare parts	%			Rs -	
Transportation	project			Rs -	
Training & commissioning	p-d			Rs -	
User-defined	cost	1	Rs 27,82,40,391	Rs 27,82,40,391	
Contingencies	%		Rs 52,20,27,000	Rs -	
Interest during construction	0.00%	0 month(s)	Rs 52,20,27,000	Rs -	
Subtotal:				**Rs 27,82,40,391**	53.3%
Total initial costs				**Rs 52,20,27,000**	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Parts & labour	project			Rs -
User-defined	cost	1	Rs 6,26,43,240	Rs 6,26,43,240
Contingencies	%		Rs 6,26,43,240	Rs -
Subtotal:				**Rs 6,26,43,240**

Periodic costs (credits)	Unit	Year	Unit cost	Amount
User-defined	cost	10	Rs 2,61,01,350	Rs 2,61,01,350
				Rs -
End of project life	cost			Rs -

FIGURE V: RETScreen Cost Analysis worksheet(Prepared for Baner SHP Analysis).

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The 'hydro formula cost method' second method of cost analysis, estimates overall project expenditure costs using the inbuilt algorithm derived from the overall expenditure costs of various small hydroelectric projects completed. Also RETScreen gives facility to enter the local price to the user. Here we entered total initial costs invested in the project manually into one of the option available in hydro formula cost method.

Project costs and savings/income summary			
Initial costs			
Feasibility study	3.0%	Rs	1,56,60,810
Development	4.2%	Rs	2,19,25,134
Engineering	4.5%	Rs	2,34,91,215
Power system	35.0%	Rs	18,27,09,450
Balance of system & misc.	53.3%	Rs	27,82,40,391
Total initial costs	100.0%	Rs	52,20,27,000
Annual costs and debt payments			
O&M		Rs	6,26,43,240
Fuel cost - proposed case		Rs	0
Total annual costs		Rs	6,26,43,240

FIGURE VI: Project Initial Cost-breakup using hydro formula.

Throughout cost analysis is performed by application considering initial investment breakup and annual expenditures (i.e. operation and maintenance) included in the proposed project as shown in Figure-6. The total initial investment is calculated Rs.52.20 Crores. The cost of Feasibility Study is 3%, Development is 4.2%, Engineering is 4.5% and Power System is 35% whereas "Balance Item and Misc. Cost" is 53.3%. Annual operating and maintainance expenditure is nearly 12% of the overall initial investment for this SHP plant.

D. Financial Analysis

A SHP plant doesn't require any fuel for power generation. Fuel is required in construction to run hardware machinary and build project setup. Thus the effective rate of fuel required will be negligible. The fuel cost escalation rate is 0% taken, 5% Inflation rate is taken and 10% discount rate is taken. The life span of project is 35 years taken because mostly of the SHP required huge amount renovation after 35 years run.

The financial analysis output includes project initial investment and income throughout life span summary, financial suitability factors, charts of cash flow cumulative and yearly. Simple payback period 8.9 years calculated, Benefit-Cost Ratio is calculated as 1.46 for export rate of Rs.1650.00/MWh. Financial stability factor shows negative summative cash flow until the 8th year and turns positive in the 9th year means that the financers starts earning from investment.

Total Initial Cost	₹	52,20,27,000.00
Total Annual Cost	₹	6,26,43,240.00
Total Annual Savings	₹	12,14,92,771.00
Net Present Value (NPV)	₹	24,23,99,946.00
Annual Life Cycle Savings	₹	2,51,34,379.00
Avg. Energy Production Cost	₹/ MWh	1,434.37
Simple Payback	Year	8.9
Benefit-Cost (B-C) Ratio		1.46

FIGURE VII: Financial Analysis.

The economical analysis of this project shows investment is sound profitable.

E. GHG Emission Analysis

The heating value reference is only required for emission analysis. The emission analysis briefly summarized GHG emissions reduction via project with compare to a conventional power plant. The net annual GHG emission reduction is 73,546 tCO_2 which is equivalent to 1,71,037 Barrels of crude oil which was not burnt.

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GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	73,546.2	0.0	73,546.2	0%	73,546.2

Net annual GHG emission reduction 73,546 tCO2 is equivalent to 1,71,037 Barrels of crude oil not consumed

FIGURE VIII: GHG Emission Analysis Worksheet.

F. Sensitivity & Risk Analysis

This section contains two worksheets mainly first one is sensitivity Analysis and second one is risk factor. The sensitivity & risk factor Analysis differs a little from each other, but both of them sensitivity & risk analyses are optional part, and this related input & output doesn't affect results in other worksheets.

V. CONCLUSION

DSS tools are computer application that can be used to support complex decision-making and problem solving such as the choice and design of RETs for financial benefits. RETScreen Clean Energy Project Analysis tool is able to estimate energy generation throughout life span of project excluding external factors, calculates initial expenditure via standard investment cost algorithm, and running cash requirement for smoothly operation and project maintenance for small hydroelectric projects in India. Faulty design and wrong selection of related turbine may leads to overrun of initial investment and also negative impact on potential efficiency, which results in less electricity generation at a higher cost.
This study is carried out to identify computer software application available in market for the easier planning of small hydroelectric project (SHP) is also gives accurate estimate for western Himalayan region or not. After this study completed at preliminary or feasibility study level and comparing values with project detail report we able to recommend this type of software and its features. The results also indicate that SHP project would be environmental favorable, and financial viable.

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