Efficient Evaluation and Ranking of 8 Hydropower sites in Indonesia Based on HPC Software and a Multi Criteria Analysis

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Introduction

The state-owned power utility Perusahaan Listrik Negara (PLN) of Indonesia is pushing the development of the electricity supply on Indonesia's numerous islands. In this context, the share of renewable energy of the country shall be increased to add to the on-grid installed capacity or replace off-grid diesel generation. Various studies for green-field small hydropower projects are available with PLN. In 2017, under the "1,000 Islands Renewable Energy for Electrification Program Project" Fichtner was assigned by PLN, under funding of Kreditanstalt für Wiederaufbau (KFW), to evaluate and rank eight pre-selected small hydropower sites in Kalimantan, Sulawesi and Papua. Based on the ranking, the five best sites were selected and in a further step, will be developed to international feasibility study level.

For all eight investigated sites, previous studies from local consulting companies are available and are used as a basis for the evaluation, the ranking of the sites and the establishment of bankable feasibility studies. The Hydropower Project (HPP) sites are all situated in remote locations, with some of them allowing access only via roads that are difficult to pass during rainy season, and some of them being located in virgin forest away from existing road infrastructure and currently not even providing foot paths. All HPP projects are planned to be linked to the local islands' electricity grids.

The first phase of the project "evaluation and ranking of the eight HPP projects" was finalized, resulting in the recommendation of five sites that are clearly to be favoured. The works for the second phase "bankable feasibility studies of five projects" were started and are currently on the way.

The following chapters describe the approach, applied for the first phase of the project, which starts with the review of the existing studies, then describes the establishment of a comparable basis and finally shows the approach applied for the evaluation and ranking of the eight projects.

1. Site Visits and Review of the Existing Studies

For the eight HPP sites under consideration, in the last decades, studies of different level of detail were carried out. The level of detail varies between pre-feasibility level to tender design level. The first step of the project was the site visit and the review of the existing studies.

1.1 Site Visits

The sites are spread over the different islands Kalimantan, Sulawesi and Papua. As Indonesia is a very large country, the longest distance between two sites of the project is more than 3,000 km. During the site visits, it was experienced that:

- Some of the sites are located in virgin forest and are difficult to access with long distance hikes through the forest. This will have an impact on the environmental sustainability.
- The access roads for other projects are in bad condition and difficult to be used during rainy season. Bridges must be constructed for HPP construction which will have an impact on project costs.
- For some sites, the steep terrain conditions will increase construction cost and access road cost.

- The river of one site is characterized by extremely high sediment load, which must be considered for the intake design in order to prevent potential sedimentation issues.

Fig. 1. Crossing the river during access to the sites.

1.2 Review of the Existing Studies

The review of the existing studies of the eight projects showed that their level of detail varies. The review considered the following points:

- Topography (reliability),
- Geology and seismicity (completeness and reliability),
- Hydrology,
- Environmental and social aspects,
- Project layout and design, and
- Project schedule.

During the review several gaps were identified:

- Existing topographic maps must be refined by additional topography surveys.
- Additional geotechnical investigations must be carried for all projects.
- The level of detail of the hydrological studies varies from project to project.
- All eight HPPs were designed with a low design discharge, varying between 50% and 75% exceedance probability, which is suitable for isolated grids. However, being connected to the grid, an increased design discharge will bring additional energy generation and ameliorate the viability.
- No Environmental or social considerations were provided in the existing studies.
- The design of the HPP layouts for most of the sites was a suitable standard design. Some gaps to be filled were identified.
- For several projects, the poor quality of access roads and the long transmission lines to the grid were not considered sufficiently.

The review of the existing studies was finalized by a gap report and recommendations for design modifications.

2. Establishment of a Comparable Basis

The review of the existing reports shows a variable level of detail among the available studies. This makes it difficult to compare the projects on common ground. Therefore, the Consultant established an own design project for each of the sites.

To create comparable data, design projects were established based on the design of the available reports, but under consideration of the design modifications recommended in the review of the studies. Further, for the establishment of the design projects a hydrological study (on the same basis for all eight projects) was carried out and the design discharge, for comparison reasons, was defined to be the flow with 30% exceedance probability.

Under consideration of the comparable basis of all eight projects, created by the Consultant, an energy generation estimation, a cost estimate and a financial/economic analysis were carried out, using the hydropower costing (HPC) software.

HPC is an inhouse developed software from the Consultant that allows to compare different options of a project or different projects on the same basis. Using HPC, the layout, the unit prices for construction material and hydrology data is entered by the user. HPC then is able to estimate the construction cost based on quantities and the unit prices, the energy generation is estimated, and a rough financial analysis is provided by the software.

The output of this part of the study makes it possible to compare the project cost, the energy generation and availability and the financial viability of the eight projects.

3. Evaluation and Ranking

To be able to compare the eight projects on an impartial basis, an evaluation matrix comprising five categories and 17 criteria was developed. Each of the criteria was weighted, based on a certain percentage. All 17 criteria together result in a value of 100%. Finally, the performance of each HPP is evaluated and classified for each of the 17 criteria with a number of points ranging between 1 and 5 and weighted with the corresponding percentage. The result of the process is an evaluation with a number of points out of five possible points for each SHPP site. The final score of each project is determined as the total count of points allowing thus the ranking of the sites.

After evaluating and ranking the eight SHPP projects, by changing the weight of the different categories a sensitivity analysis is carried out, which assessed the robustness of the developed ranking.

3.1 Evaluation matrix

The evaluation matrix provides the following five categories which were equally weighted:

- Technical Feasibility,
- Energy & Power,
- Financial Performance,
- Socio Environmental Assessment, and
- Risk.

The categories were subdivided into 17 criteria in total which were weighted with a certain percentage. The following table shows the Evaluation Matrix with its weight distribution over the categories and criteria.

Category	Weight distribution among categories	Criteria	Weight distribution among criteria
Technical Feasibility	20.0%	Accessibility for Construction	6%
		Connection to the Grid	6%
		Difficulty of Implementation	8%
Energy & Power	20.0%	Energy Generation [GWh/a]	6%
		Power Demand [MW] / Power Generation [MW]	8%
		Installed Capacity [kW]	6%
Financial Performance	20.0%	Levelized Electricity Cost LEC [USD/kWh]	6%
		Specific Cost [USD/kW]	4%
		Internal Rate of Return IRR	10%
Socio-Environmental Assessment	20.0%	Restricted / protected areas	5%
		Natural Area occupied [ha]	7%
		Categorization according to KfW Guidelines	5%
		Human Assets Area Occupied (crops, houses, sacred places)	3%
Risk	20.0%	Geological Risk	4%
		Hydrological Risk	4%
		Legal Risk (Approval & Licensing)	8%
		Risk of deforestation of catchment area	4%
Total	100%		100%

Fig. 2. Evaluation Matrix.

For each criterion a rating was determined in the range from 1 point for poor conditions to 5 points for good conditions. These points are later weighted according to the weight distribution and summed up, which results in the overall rating of the project. According to these ratings the projects will be ranked.

For the sensitivity analysis of the ranking, the weightings of the categories are modified. Four cases are evaluated:

- Case 1 (base case): Equal distribution,
- Case 2: Energy and Power prioritized,
- Case 3: Financial performance prioritized, and
- Case 4: Socio environmental Assessment prioritized.

For the cases 2 to 4 the weighting of the prioritized category was increased to 40% and the other categories decreased accordingly. The 40% weighting increment is based on the author's experience:

3.2 Result of the Evaluation and Ranking

The result of the above evaluation is illustrated in the figure below. The figure shows the ranking of the eight small hydropower sites and their percentage of the full points reached. The result shows the following:

- There is one site that clearly reached the highest percentage. The SHPP Site 1 reached 74 % which is 4 % more than the second place.
- Two sites, Site 2 and Site 3 on second and third place, with 70 % and 66 % are similar as far as their ratings are concerned.
- Site 4 and Site 5 with 61 % and 58 % are on fourth and fifth place.
- The last three projects, are below 50% which is clearly less than the other projects.

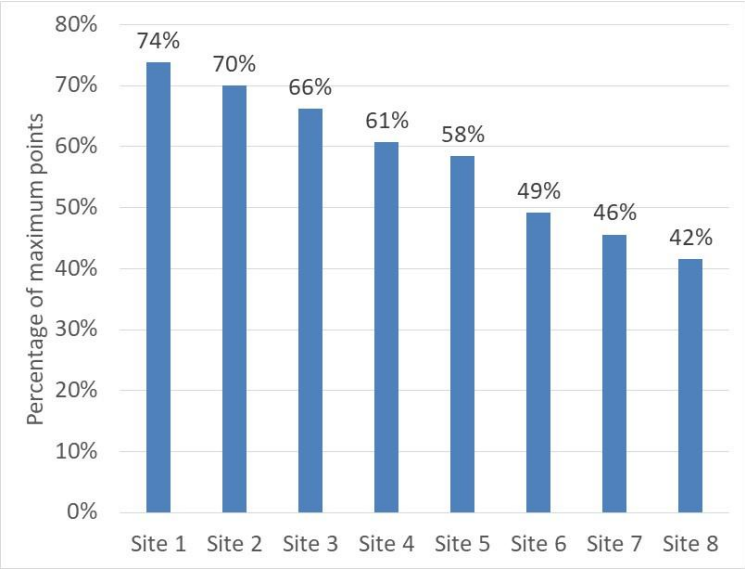

Fig. 3. Result of the evaluation and ranking.

The sensitivity analysis, with changed priorities, showed that the result is stable. The best five sites, in all cases, are better than the last three sites. The following table shows the result of the sensitivity analysis.

		Rank							
Case	Priority	Site 6	Site 8	Site 7	Site 5	Site 3	Site 4	Site 2	Site 1
Case 1	Equally Weighted	6	8	7	5	3	4	2	1
Case 2	Priority on Power and Energy	7	8	6	4	3	5	2	1
Case 3	Priority on Financial	6	8	7	5	3	4	1	2
Case 4	Priority on Environmental	6	8	7	5	2	3	4	1
	Average	6.25	8	6.75	4.75	2.75	4	2.25	1.25

Fig. 4. Result of the sensitivity analysis.

4. Result and Recommendation

After the evaluation of the eight sites the clear recommendation is to select the sites 1 to 5 for further development, where one project is located in Papua, one project is located in Sulawesi and three projects are located in Kalimantan. These five projects provide a relatively good viability and a higher amount of energy that is produced. Compared to the last three projects which are located in Kalimantan, their environmental impact is estimated to be low, as access roads close to the site are already existing.

The three remaining projects in Kalimantan were last in the ranking. They all are located in virgin forest and therefore require several kilometres of new road construction through the forest. That is a problem concerning environmental acceptance and causes high construction cost. Further, their hydropower potential and viability are lower than for the other projects.

The Authors

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