Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.8, No.3, 2018

Multi-Criteria Decision Making for Sustainability of Renewable Energy System of Nepal

Ram Prasad Dhital PhD Candidate
Mechanical Department, Pulchowk Campus,
Institute of Engineering, Tribhuwan University, Nepal
Corresponding email: rpdhital@yahoo.com

Tri Ratna Bajracharya
Dean, Pulchowk Campus, Institute of Engineering
Tribhuvan University, Nepal

Rajendra Shrestha
Mechanical Engineering Department, Institute of Engineering
Tribhuvan University, Nepal

Abstracts

This paper presents an application of Analytic Hierarchy Process for evaluation of the sustainability of renewable energy sources and technology in context of Nepal. Solar energy, biogas, micro hydropower and grid technology have been evaluated based on selected criteria like technical (efficiency and reliability), economic (initial investment, operation & maintenance cost and Benefits), environmental (CO_2 emission, land requirement, impact on ecosystem) and social (social acceptability, job creation, social benefits). The importance weights of the criteria and sub-criteria as well as preferential ranking of options have been determined by eliciting expert judgment through pairwise comparisons. The findings show that within the technological constraints, grid technology is the most preferred option followed by micro hydropower and Solar. Biomass is the least preferred sustainable system of Nepal. The finding also shows that technical criteria (33%) is the most important criteria for renewable energy followed by financial (27%), Environmental (22%) and social (18%) being the least. In context of Nepal, Financial criteria has more priority than the environment by the experts for financial sustainability of renewable energy as most of the projects are one time funded by government or donor agencies. The proposed evaluation will help to select the most suitable alternative assisting policy makers to form opinion on sustainability of considered energy systems and make decisions on optimum alternative. However, as time progresses and technology improves, the preferential ranking might change.

KEYWORDS: *Analytical Heirarchy Process, Sustainability, Renewable Energy, Pairwise Comparison, Alternatives*

1. Introduction

The high consumption and population growth forces the inhabitants of many countries to deal with the critical problem of dwindling domestic fossil energy resources. Many countries all over the world are keeping the effort to make the effective energy planning for achieving a sustainable energy system.

In Nepal, renewable energy contributes merely 1% in total energy mix; however it electrifies 12% of the total population mostly in rural areas [1]. About 90% of the rural customers connected to the grid consume less than 20 kWh per month making on grid electrification financially unattractive in rural Nepal [2]. In this context, renewable energy has become the viable means of rural electrification in Nepal. Realizing the importance of renewable energy in rural areas, the Government of Nepal in its interim three year plan (2010 to 2013) considers rural electrification through renewable energy technologies is an appropriate means to enhance rural livelihoods and conserve environment in rural areas.

Renewable energy is emerging as a solution for a sustainable, environmentally friendly and long term, cost-effective source of replacing conventional sources of energy in most of their applications at competitive long term prices. Selecting the appropriate source of energy in which to invest is a task that involves different factors and policies. Renewable energy decision-making can be viewed as a multiple criteria decision-making problem with correlating criteria and alternatives. This task should take into consideration several conflicting aspects because of the increasing complexity of the technical, economic, environmental and social factors. Traditional single criteria decision-making approaches cannot handle the complexity of current systems and this problem. Multi-criteria methods provide a flexible tool that is able to handle and bring together a wide range of variables appraised in different ways and thus offer useful assistance to the decision maker in mapping out the problem. As this work demonstrates, multi-criteria analysis can provide a technical-scientific decision-making support tool that is able to justify its choices clearly and consistently, especially in the renewable energy sector.

There are several techniques now available in the literature to deal with multi criteria decision-making problem [3], [4], [5]. Some of the well-known techniques are Multi Attribute Utility (MAU) model, Simple Multi Attribute Rating Technique (SMART), Analytic Hierarchy Process (AHP) and Fuzzy Hierarchical Decision Making (FHDM) method. Among these AHP is possibly the most familiar and extensively used MCDM method. It is simple and easily comprehensible. In spite of some criticisms leveled against it [6], [7], [8], this method has been widely applied in many MCDM problems.

Brief overview of Energy Source of Nepal

A. Solar Energy

Solar energy is the radiant energy produced by the sun in the form of light and heat. On average, Nepal has 6.8 hours of sunshine per day with the intensity of solar insolation ranging from 3.9 to 5.1kWh/m^2 (national average is about 4 kWh/m^2/day [9]. The overall scenario of solar energy prospect in Nepal is good enough for application in power generation.

Amongst the various technologies developed in solar thermal system, Solar PV systems are gaining popularity in some parts of Nepal. This is because the majority of the population live in rural areas has limited access to electrical energy, the cost of a diesel generator is high, biogas plants are not feasible in cold high altitudes, and small hydro turbines require specific topographical conditions which are not possible in many places. The estimated market potential is huge and about 8278.9kW of PV power is currently being used in various public and private sectors in Nepal [1].

B. Biomass

Nowadays biogas has been recognized as an attractive and viable energy source. Sustainable use of forest to meet national energy demand using energy efficient conversion technology like efficient cooking stoves and gasifiers, and waste to energy generation are necessary to ensure ecological balance as well as to have energy security. Biomass has been proving and is becoming a promising source of alternative fuel for transportation in large global economy as well. The end-use of products from biomass conversion can be mainly in any one of heat and power applications, transportation fuels (biodiesel, bio-ethanol) and chemicals for subsequent processing. [10]. Experts remark that this source of energy has good prospect in the context of Nepal especially in the rural places.

C. Micro Hydropower

The theoretical and commercial potentials of hydropower in Nepal are estimated to be about 83,000 MW and 42,000MW respectively. Realizing the huge hydropower potential, many renewable energy development programs have focused on the development of micro-hydro plants. Electrical energy can be obtained from a micro-hydro system either instantaneously or through a storage system. In an instantaneous power demand system, the system provides 240V AC power to the load via-a turbine which must be sufficiently large to meet the peak power demand [11]. Most of the rivers are seasonal and during winter, the discharge is very low, causing higher insecurities in energy supply.

D. Grid Technology

Power Grid is an electric power infrastructure of bulk power system consisting of generation, transmission, and distribution systems that provides electrical energy to the consumers safely, reliably, and as economically as possible, through complex but coordinated control networks. Grid Technology involves small-scale generation sources such as solar PV, wind turbines, micro hydropower, bio-fuels, and other non-utility scale generation sources that meet local level demands through micro grid. However, in the long run, industrial-scale wind, solar generation plants, and PHEV (Plug in Hybrid Electric Vehicle) can feed the grid as well [12]. AEPC's report on solar and wind energy resource assessment in Nepal (SWERA) state that the commercial potential of solar power for grid connection is only 2100MW. Overall, the exploitation of this potentiality will largely depend on the acceptability and affordability of the technology [13].

2 Material and Method

The research methodology is based on co-relational approach. AHP framework in which hierarchical criteria and sub-criteria were determined from literature findings (published journal and articles) and pilot testing through experts opinion. Pairwise comparison questionnaire were prepared for comparing each pair of the criteria, sub-criteria and alternatives used in the selection and to identify to what extent one criterion or alternative is more or less important or preferred to another. The respondents to this questionnaire were a committee of experts in the field of energy sectors. Their preferences are recorded in Saaty scale of 1-9, consistency ratio is checked for verification and weightage are generated.

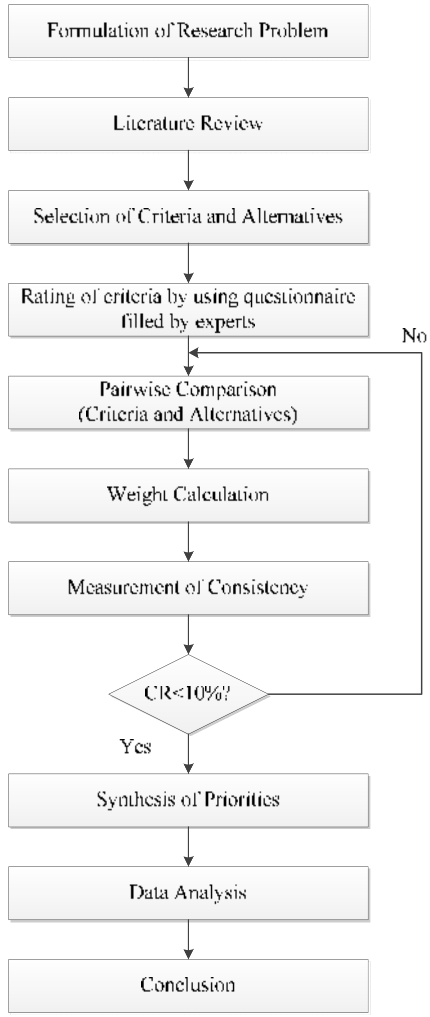

Figure 1: Research Methodology

2.1 Analytical Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) was first introduced by Thomas Saaty (1977) as an effective tool to deal with complex decision making [14]. AHP is used for ranking various decision alternatives and selecting the best one [10]. The process starts by describing the problem in a hierarchical structure including in the highest level an overall (quantifiable) goal further decomposed in criteria and sub-criteria whereas in the lowest level alternative solutions to attain the goal are found. The approach is applicable in situations where decision-makers and experts are available. The decision-makers needs to define the goal and can distinguish alternative solutions to attain it whereas experts are required to evaluate the alternative solutions based on criteria [16]. After structuring the problem, AHP is used to compute the weights for the different criteria. Pairwise comparison matrixes are constructed starting from the first level of criteria and continuing to lower levels, comparing criteria on the same level under the same nod. Individual preferences are converted into ratio scale weights that generate linear additive weight for each alternative. All the criteria have been rated from scale 1 to 9 versus all other criteria, as stated in the Table. 1 [17], [18], [19].

Table 1: AHP Approach

Preference Weights	Definition
1	Equally Preferred
3	Moderately Preferred
5	Strongly Preferred
7	Very Strongly Preferred
9	Extremely Preferred
2,4,6,8	Intermediates Values
Reciprocals	Reciprocals for inverse comparison

Based on the ratings obtained through the questionnaire, matrixes are formed and the priorities are synthesized using the methodology of AHP. The decision maker compares the weightage given to several alternatives and selects the best alternative that meets the decision criteria. Numerical scores are assigned to rank each decision alternative based on how well the alternative meets the decision maker's criteria. AHP is viable to formulate the desired decision making criteria, to determine the level of importance of different decision-making criteria, and to obtain the best decision [20].

Major steps used in AHP which are described as follows:

1. ***Describing Evaluation Issues***: It is the initial step where an unstructured problem is defined and goal is determined. This includes structuring the hierarchy from the top (objectives from a decision-makers viewpoint) through intermediate levels (criteria on which subsequent levels depend) to the lowest level, which typically contains a list of alternatives.
2. ***Identification of Criteria***: This step indulges with selecting related performance criteria and selection of appropriate criteria based on the process of reviewing and the relevant literature and interviewing experts. These criteria should be mutually exclusive and their priority or importance does not depend on the elements below them in the hierarchy [21], [22].
3. ***Construction of Hierarchy Structure***: A hierarchy structure is established from the top through the intermediate levels to the lowest level which usually contains the list of alternatives. In order to lessen the complexity of the consistency, the criteria for each alternative should contain no more than seven elements, and keep independence individually [21].
4. ***Pair-wise Comparison***: The pair-wise comparisons of elements are made in each group. Saaty developed the fundamental scale for pair-wise comparisons [18]. The pair-wise comparison matrix A, in which the element a_{ij} of the matrix is the relative importance of the i^{th} factor with respect to the j^{th} factor, could be calculated as

$$A = \left[a_{ij}\right] = \begin{bmatrix} 1 & a_{12} & \Lambda & a_{1n} \\ 1/a_{12} & 1 & \Lambda & a_{2n} \\ M & M & O & M \\ 1/a_{1n} & 1/a_{2n} & \Lambda & 1 \end{bmatrix} \quad \ldots\ldots\ldots\ldots (1)$$

Where, a_{ij} is the comparison between element i and j.

$$a_{ii} = 1;\ a_{ji} = \frac{1}{a_{ij}}\ ;\ \text{for i, j = 1, 2, …., n;}\ \det A \neq 0$$

There are n(n-1)/judgments require developing the set of matrices. Reciprocals are automatically assigned to each pair-wise comparison, where n is the matrix size. The establishment of paired matrices A lead to determining the weights of the criteria within each hierarchy [22].

Through pair-wise comparison the ratio-scaled importance or priorities of each alternative is calculated. Eigenvalues are calculated after pairwise comparison is done.

Hierarchical synthesis is now utilized to weight the eigenvectors according to weights of criteria. The sum is for all weighted eigenvectors corresponding to those in the next lower hierarchy level. Having made all pair-wise comparisons, consistency is identified by using the Eigen value λ_{max}, to calculate the consistency index. Saaty (1994) proposed that the largest Eigen value [23],

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} \frac{W_j}{W_i} \text{ ………….. (2)}$$

Where, λ_{max} is the principal or largest Eigen value of positive real values in a judgment matrix; W_j is the weight of j^{th} factor and W_i is the weight of i^{th} factor.

Priorities obtained from the comparison are used to weigh the priorities in the level immediately below. This is done for every element. Then for each element in the level below, its weighed values are added to obtain its overall or global priority. It process is continued to until the final priorities of the alternatives in the bottom most level are obtained.

5. ***Consistency Test***: Each pair-wise comparison contains numerous decision elements for the consistency index (CI), which measures the entire consistency judgment for each comparison matrix and the hierarchy structure. Saaty (1994) utilized the CI and consistency ration (CR) to assess the consistency of the comparison matrix. The CI and CR are defined as,

$$CI = \frac{\lambda_{\max} - n}{n - 1} \text{ ………….. (3)}$$

Where, n is the matrix size.

$$CR = \frac{CI}{RI} \text{ …..……. (4)}$$

Where, the judgment consistency can be checked by taking the CR of CI with the appropriate value Table 2.

Table 2: Average Random Consistency (RI) [24]

Size of Matrix	1 , 2	3	4	5	6	7	8	9	10
Random Consistency	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The CR is acceptable if it does not exceed 0.10. The CR is > 0.10, the judgment matrix is inconsistent. To acquire a consistent matrix, judgments should be reviewed and improved.

6. ***Normalization***: This study normalized the weight of the interval level and connected the local weight to acquire the global weights of the criteria in each hierarchy after calculating the weights of all criteria [21].

   Calculation of norms for each j column of the matrix of decision making:

   $$Norma_j = \sqrt{\sum_{i=1}^{m} x_{ij}^2}$$

   j = 1, 2, …., n

   Where: x_{ij} - value of the j attribute by the i alternative.

   Calculating the normalized matrix elements of decision making.

   For attributes of type max: $n_{ij} = \frac{x_{ij}}{Norma_j}$

   For attributes of type min: $n_{ij} = 1 - \frac{x_{ij}}{Norma_j}$

7. ***Linearization***: The linearization is doing with the aim of reducing the value of the attribute at the interval (0,1) and translation of various units of measure in the unnamed number.

Table 3: Criteria and Sub-criteria for Sustainability Assessment

Criteria	Sub-Criteria	Literature
Technical	Efficiency	[26], [27], [28]
	Reliability	[25], [26], [29], [30], [31]
Economic	Initial Investment	[25], [26], [27], [30], [31]
	Operation and Maintenance Cost	[26], [35], [36]
	Benefits (Tariff)	[26], [27], [32]
Environmental	CO_2 Emission	[25], [26], [32], [37]
	Land Requirement	[26], [32], [38]
	Impact on Ecosystem	[25], [39], [40], [41]
Social	Social Acceptability	[25], [26], [29]
	Job Creation	[26], [27], [29]
	Social Benefits	[25], [26], [27]

2.2 Model Analysis

Pairwise Comparison and Computations for Criteria

A survey questionnaire approach was used for gathering the data to assess the order of importance of the evaluation criteria. From the hierarchy tree, we developed a questionnaire to enable pairwise comparisons between all the selection criteria at each level in the hierarchy. The pairwise comparison process elicits qualitative judgments that indicate the strength of a group of decision makers preference in a specific comparison according to Saaty's 1-9 scale. A group of experts from energy sector was requested to respond to several pairwise comparisons where two categories at a time were compared with respect to the goal. Result of the survey questinnaire technique was then used as input for the AHP. It took a total of 6 judgments (i.e 4*(4-1)/2) to complete the pairwise comparisons. The other entries are 1's along the diagonal as well as the reciprocalls of 6 judgments. The shown in the matrix can be deployed to derive estimate of the criteria priorities. The priorities provide a measure of the relative importance of each criterion. Essentially, the following three steps can be utilized to synthesize the pairwise comparison matrix.

1. Total the elements or values in each column
2. Divide each element of the matrix by its column sum
3. Determine the priority vector by finding the row averages

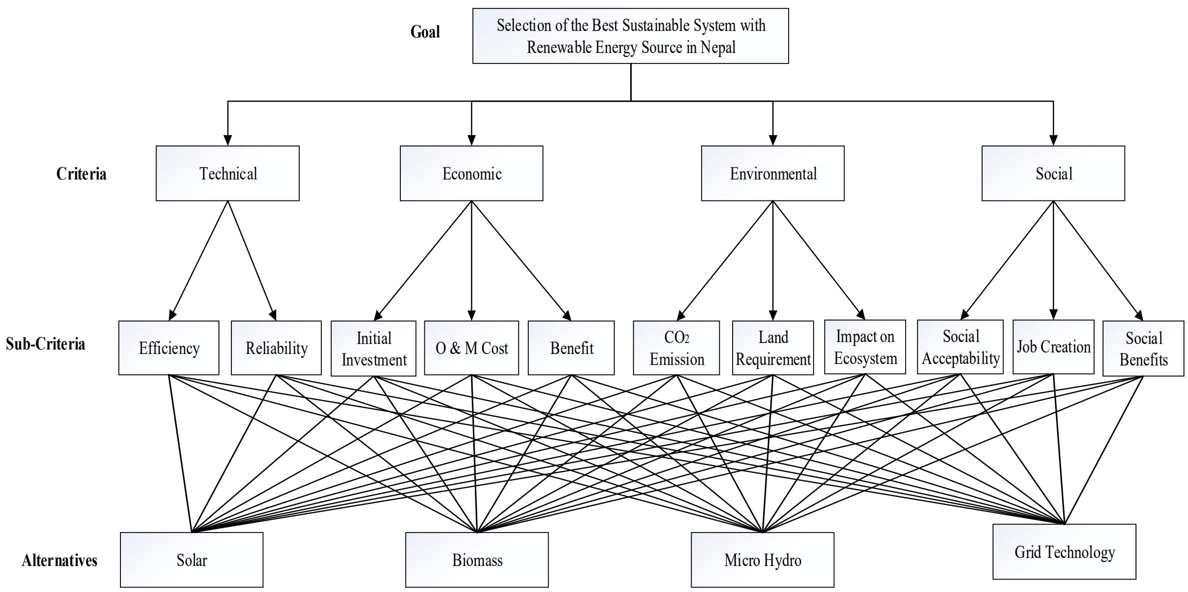

Figure 2: AHP Model of the Best Sustainable System with Renewable Energy Source

3 Result

Initially, pair-wise comparison of criteria with respect to the goal was done. Results of the weight obtained for different is shown in Table 4. Technical criterion is identified as the most important criteria (33%). Economic criterion is the second most important criterion with 27% weight. Social criterion has the lowest weight amongst all criteria. The overall consistency ratio (CR) were than 0.1 (desirable value), so the model was validated. Priorities weights of sub-criterion are illustrated in Figure 3.

Table 4: Priorities of Criteria and Sub-Criteria for Evaluating Alternatives

<table>
<tr><th>Criteria</th><th>Global Weightage</th><th colspan="2">Sub-Criteria</th><th>Local Weightage</th><th>CR %</th></tr>
<tr><td rowspan="2">Technical (A)</td><td rowspan="2">33%</td><td colspan="2">Efficiency (A2)</td><td>33%</td><td rowspan="2">0.67%</td></tr>
<tr><td colspan="2">Reliability (A3)</td><td>67%</td></tr>
<tr><td rowspan="3">Economical (B)</td><td rowspan="3">27%</td><td>Initial Investment (B1)</td><td rowspan="3">Benefit/Cost Ratio</td><td rowspan="3">26%</td><td rowspan="3">0.03%</td></tr>
<tr><td>O & M Cost (B2)</td></tr>
<tr><td>Benefits (Tariff)</td></tr>
<tr><td rowspan="3">Environmental (C)</td><td rowspan="3">22%</td><td colspan="2">CO2 Emission (C1)</td><td>30%</td><td rowspan="3">0.45%</td></tr>
<tr><td colspan="2">Land Requirement (C2)</td><td>29%</td></tr>
<tr><td colspan="2">Impact on Ecosystem (C3)</td><td>49%</td></tr>
<tr><td rowspan="3">Social (D)</td><td rowspan="3">18%</td><td colspan="2">Social Acceptability (D1)</td><td>28%</td><td rowspan="3">0.23%</td></tr>
<tr><td colspan="2">Job Creation (D2)</td><td>36%</td></tr>
<tr><td colspan="2">Social Benefits (D3)</td><td>36%</td></tr>
</table>

The criteria were breakdown into sub criteria where the weightage are shown in the Figure 3. Reliability was the most important sub criteria for evaluating the alternatives while Primary Energy Ratio contributes least for ranking the alternatives.

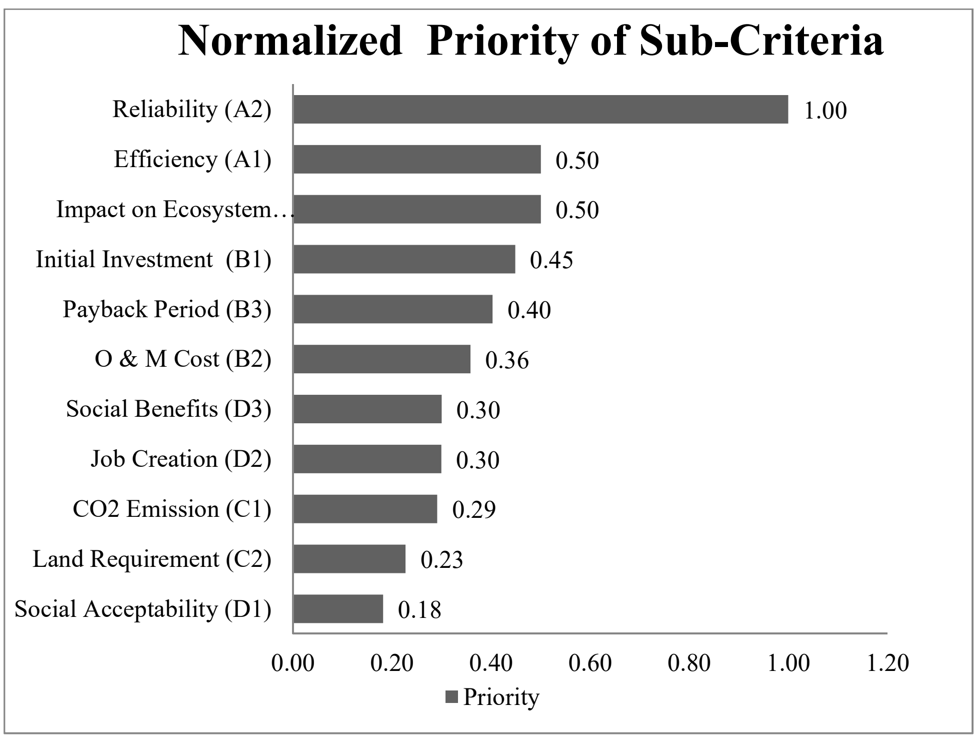

Figure 3: Priority Weights for Sub-Criteria with Respect to goal

Table 5 shows the weight received by alternatives for each criterion. Grid Technology is ranked at the top of the priority which is followed by Micro Hydropower and Solar. Biomass is the least sustainable system with renewable energy sources of Nepal

Table 5: Weight Received by Alternatives for Each Criterion

Alternatives	Technical	Economic	Environmental	Social	Total	Rank
Solar	5.35%	6.66%	7.55%	3.49%	23.05%	3
Biomass	3.37%	6.27%	3.34%	2.63%	15.61%	4
Micro Hydropower	10.57%	7.29%	5.18%	6.38%	29.42%	2
Grid Technology	14.16%	6.38%	5.56%	5.82%	31.92%	1

Normalized performance scores of the sustainability of energy system are shown in the Figure 4 where alternatives are ranked in the order from top to below. It depicts grid technology were performing better while biomass were an underperforming energy system based on selected criteria and sub-criteria.

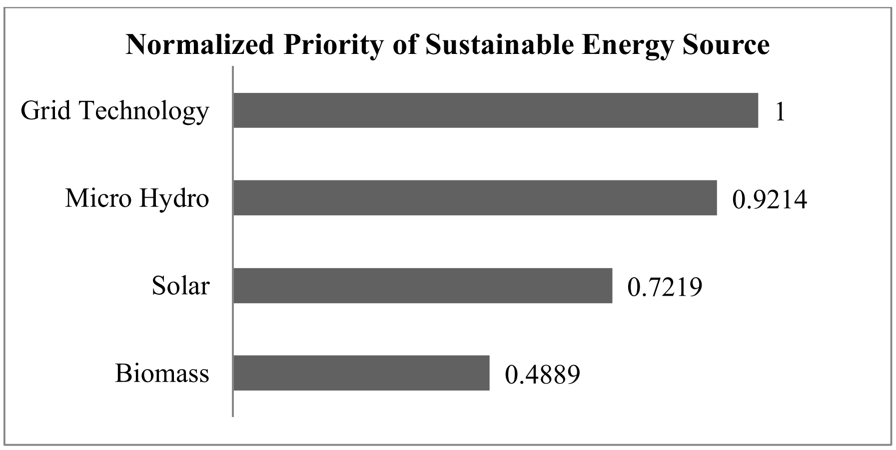

Figure 4: Normalized Ranking of Sustainability of Energy System

3.1 Sensitivity Analysis

Sensitivity analysis as shown in figure 5 lets evaluator to observe how final evaluation is likely to change. It also helps in measuring how much changes made by certain extent of deviation in weights of criteria. Simulation of sensitivity analysis is carried out by making gradual changes on values of each criterion, whether Technical, Economic, Environmental or Social, and then observing the rank order due to such changes.

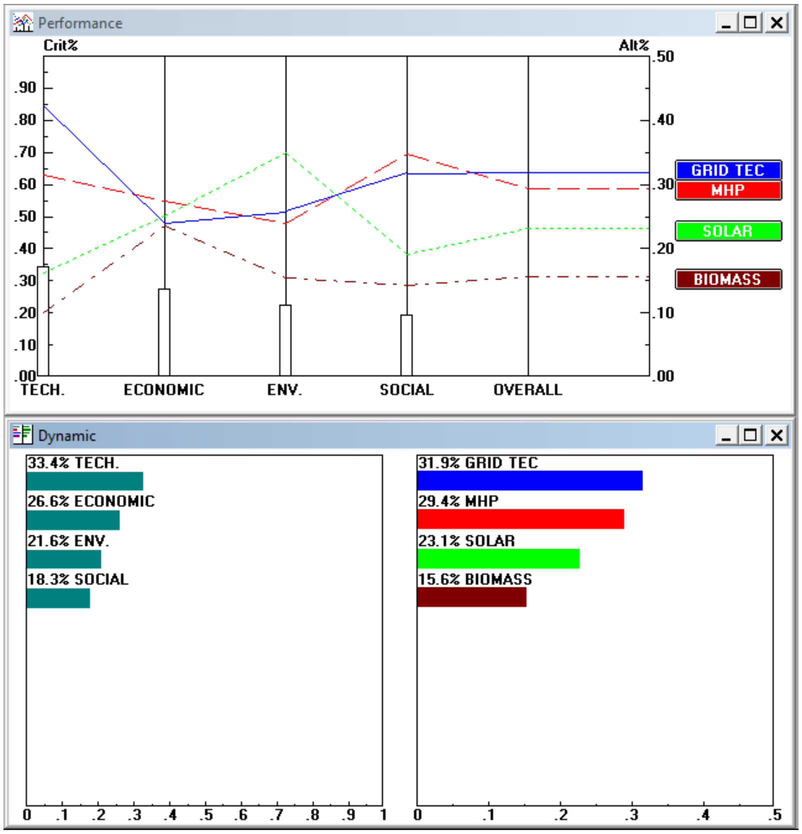

Figure 5: Final Evaluation of Sustainable Energy System with Sensitivity Analysis

The result of the validation shows that Grid Technology (31.9%) is the most efficient sustainable energy system of Nepal. The main reason for such a result is the highest local priority of the technical Criteria, which were recognized as the most important criteria's from the developed model. Biomass (15.6%) is deemed to be least efficient sustainable energy system. Biomass has to improve its technical, environmental and social criteria so as to improve its ranking.

4 Conclusion

Renewable energy sources and new technologies which use these sources are becoming increasingly important segment in all areas, especially in the energy sector. Using renewable energy has reduced consumption of nonrenewable energy resources. Result indicate that grid technology is the most sustainable energy system (overall normalized efficiency = 100%) while biomass is the least sustainable energy system with normalized efficiency of 48.89%.

Experts have emphasized on technical criterion as the technical expertise present in the country is well below par. Since, Nepal is a developing country with limited financial resources; economic criterion has weighted very high compared to environmental and social criteria. Social criterion is the least important criterion. This could be because of the fact that proclivity of the end users to adopt these technology is comparatively low.

The sensitivity analysis shows that Solar need to increase its Technical and Financial criteria to improve its ranking whereas biomass has to improve its technical, environmental and social criteria so as to improve its ranking. Overall, based on sensitivity analysis, it can be concluded that the final decision is consistent and reliable.

8. Reference

[1] AEPC, A. E. (2012). *Annual Report.* Kathmandu: AEPC.
[2] Mainali, B., & Silveira, S. (2011). Financing off grid electrification.Country case Nepal. *Elsevier*, 2194-2201.
[3] Goodwin, P. and Wright, G. (1998). *Decision Analysis for Management Judgment, (2nd edition).* Chichester: John Wiley & Sons.
[4] Saaty, T. (1980). *The Analytic Hierarchy Process.* New York: McGraw Hill.
[5] Keeney, R.L. and Raiffa, H. (1976). *Decision with Multiple Objectives: Preferences and Value Tradeoffs.* New York, Wiley.
[6] Van Laarhoven, P.J.M. and Pedrycz, W. (1983). A Fuzzy Extension of Saaty's Priority Theory. *Fuzzy Sets Sys., 11*, 229-241.
[7] Belton, V. and Gear, T. (1983). On a Shortcoming of Saaty's Method of Analytical Hierarchy. *Omega, 11(3)*, 226-230.
[8] Belton, V. and Gear, T. (1985). The Legitimacy of Rank Reversal – A Comment. *Omega, 13(3)*, 143-144.
[9] Shrestha, J. N. (2006). Solar Radiation in Nepal: its implications in telecommunication services. *In Proceedings of first national conference in renewable energy technology for rural development*.
[10] Baral, B., Karki, S. and Pandey, S. (2013). Biomass Energy Technology Research in Nepal: A Review. *Rentech Symposium Compendium, 3*.
[11] Adhikari, D. (2015). Hydropower Development in Nepal. 74-76.
[12] Gajurel, S. (2016). Smart Grid- A New Paradigm to Power Grid . *The International Research Journal of Management Science, 1(1)*, 2542-2510.
[13] KC, S., Khanal, S.K., Shrestha, P. and Lamsal, B. (2011). Current Status of Renewable Energy in Nepal: Opportunities and Challenges. *Renewable and Sustainable Energy Reviews, 15*, 4107-4117.
[14] Saaty, T. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology, Vol.15(3)*, pp. 234-281.
[15] Taylor, B. W. (2010). Introduction to Management Science, 10th ed. Prentice Hall, New Jersey.
[16] Rezaei, J. & Ortt, R. (2013). Multi-criteria supplier segmentation using a fuzzy preference relations based AHP. *European Journal of Operational research, 225(1)*, 75-84.
[17] Crowe, T.J., Noble, J.S. and Machimada, J.S. (1998). Multi-Attribute Analysis Of ISO 9000 Registration Using AHP. *International Journal of Quality And Reliability Management, 15(2)*, 205-222.
[18] Saaty, T. (2000). *Fundamentals of Decision Makingand Priority Theory. 2nd ed.* Pittsburgh, PA: RWS Publications.
[19] Hafeez, K., Zhang, Y. and Malak, N. (2002). Determining Key Capabilities of A Firm Using Analytic Hierarchy Process. *International Journal of Production Economics, 76 (1)*, 39-51.
[20] Guller, M.E. (2008). Incorporating MultiCriteria Considerations into Supplier Selection Problem Using Analytic Hierarchy Process:A Case Study. *Journal of Yasar University 3 (12)*, 1787-1810.
[21] Fu, H. and Lin, S. (2009). Applying AHP to analyse criteria of performance measurement for national energy promotion projects. *International Journal of Electronic Business Management, Vol. 7*, No. 1, 3-16.
[22] Bahurmoz, A. (2006). The Analytic Hierarchy Process: A Methodology for Win-Win Management. *JKAU: Econ. & Adm., 20 (1)*, 3-16.
[23] Saaty, T. L. (1994). *Fundamentals of Decision Making and Priority Theory.* RWS Publications, Pittsburgh.
[24] Balaji, M.,Madhumathi, P., Karuppusami, G.and Sindhuja, D. (2012). AHP Based Agile Supply Chains. *International Journal of Engineering and Innovative Technology (IJEIT), Vol.1 (2)*.
[25] Stonjanovic, M. (2013). Multi-criteria decision-making for selection of renewable energy systems. 115-120.
[26] Shahriari, G., Hosseini, S.M.,S. and Hosseinalipoor, S.M. (2011). Optimal Sustainable Energy Portfolio in Tehran Province Industries using Fuzzy AHP. *Australian Journal of Basic and Applied Science, 5(12)*, 2584-2594.

[27] Doukas, H.C., Andreas, B.M. and Psarras, J.E. (2007). Multi-criteria decision aid for the formulation of sustainable technological energy priorities using linguistic variables. *European Journal of Operational Research* , 844-855.

[28] Prindle, B., Eldridge, M., Eckhardt, M. and Frederick,A. (2007). *The twin pillars of sustainable energy: synergies between energy efficiency and renewable energy technology and policy.* Washington DC.

[29] Chatzimouratidis, A.I. and Pilavachi, P.A. (2008). Multicriteria evaluation of power plants impact on the living standard using the analytic hierarchy process. *Energy Policy 2008;36*, 1074–1089.

[30] Akash, B.A., Mamlook, R. and Mohsen, M.S. (1999). Multi criteria selection for a wind observation station location using analytical heirarcy process. *Electr Power Syst Res*, 29-35.

[31] Kahraman, C., Kaya, I. and Cebi, S. (2009). A comparative analysis for multi-attribute selection among renewable energy alternatives using fuzzy axiomatic design and fuzzy analytic hierarchy process. *Energy; 24*, 1603-1616.

[32] Wang, J.J., Jing, Y,Y,Zhang, C,F, Shi,G.H. and Zhang, X.T. (2008). A fuzzy multi-criteria decision- for trigeneration system. *Energy Policy*, 3823–3832.

[33] Beccali, M., Cellura, M. and Mistretta, M. (2003). Decision-making in energy planning. Application of the electre method at regional level for the diffusion of renewable energy technology. *Renewable Energy 2003,33*, 2063–2087.

[34] Cavallaro, F. and Ciraolo, L. (2005). A multicriteria approach to evaluate wind energy plants on an Italian island. *Energy Policy ; 33*, 235–244.

[35] Pilavachi, P.A., Stephanidis, S.D., Pappas, V.A. and Afgan, N.H. (2009). Multi-criteria evaluation of hydrogen and natural gas fuelled power plant technologies. *Applied Thermal Engineering 2009, 29*, 2228–2234.

[36] Chattopadhyay, D. and Ramanathan, R. (1998). A new approach to evaluate generation capacity bids. *IEEE Transactions on Power Systems*, 1232–1237.

[37] Kiehl, J.T. and Trenberth, K.E. (1997). Earth's annual global mean energy budget. *Bulletin of the American Meteorological Society*, 197–208.

[38] Huang Fu, Y., Wu, J.Y., Wang, R.Z. and Huang, X.H. (2005). Study on comprehensive evaluation model for combined cooling heating and power system (CCHP). *Journal of Engineering Thermophysics*, 13–16.

[39] Kablan, M. (1997). Prioritization of decentralized electricitiy options available for rural areas in Jordan. *Energy Convers Management 38*, 1515-1521.

[40] Nava, M.R. and Daim, T.U. (2007). Evaluating alternative fuels in USA: A proposed forecasting framework using AHP and scenarios. *Int J Automoot Technol management 7*, 289-313.

[41] Nigim, K., Munier, N. and Green, J. (2004). Pre-feasibility MCDM tools to aid communities in prioritizing local viable renewabl energy sources. *Renewable energy 29*, 1775-1791.