"Qualitative Analysis to Assess the Best Renewable Energy Scenario for Sustainable Energy Planning"

Sachin S. Ingole, Satish G. Bahaley, Sumit S. Kalmegh, Sumit S. Jamkar

Abstract*: *Rural population in developing nation is having limited access to the clean and modern energy sources. Rural poor in India are mostly dependent on electricity, fire wood, dung, and biomass for their domestic energy need. Due to the dependence on conventional energy sources pollution and rural health are the issue of concern which directly affect on the national productivity. Ministry of New and Renewable Energy of the Government of India giving stress to intensify the energy supply and modern sources of energy to rural area up to normal consumption level through renewable energy sources The aim of the present study is to determine the best renewable energy scenario for sustainable development of rural area. For this aim, author used both quantitative and qualitative analysis technique to determine the best energy scenario for application. For quantitative analysis multi objective goal programming model is used and the result obtained by it validated with multi-attribute decision making approach. The present work specifically focused on Analytic Hierarchy Process (AHP) methodology. In the proposed method, the weights of the selection criteria are determined by pair-wise comparison matrices of the AHP. Results indicate that Cost Employment Generation Scenario (CEGS) is the most appropriate renewable energy option.

Keywords: AHP; Multi-Criteria Decision Making, Renewable Energy; Sustainable Energy Planning; Scenario.

I. INTRODUCTION

Estimation shows that the electricity consumption of the world will reach up to 24,400 billion KWh by the year 2020. Economical and environmental are the key parameters to select the primary energy resources required to provide this consumption, since 85% of greenhouse gas emissions worldwide are sourced by the energy sector today [01].

Multiple factors are involved in decision making process. Factors may be quantitative or qualitative in nature. It becomes quite intricate for evaluator to decide feasible solution as the complexity of the problem increases. The evaluating should cover technical, economical environmental and social aspects which may not be easily identifiable; simultaneously these factors affect the interest of various stakeholders. In the view of these difficulties, AHP method may be useful in undertaking difficult assessment procedures [02]. In past various studies has been conducted on energy issues by MCDM technique. The evaluation criteria used in these studies are technical, economical, environmental, and social [03]. For the sustainable development of region it is necessary to reduce the dependence on imported supply. It is the necessity of the time to sensitively evaluate the locally available traditional and renewable energy sources, and it should be augmented from an environment and health aspect. Detailed literature review has been carried out to identify the appropriate method for solving the energy planning problem. The review of both quantitative and qualitative analysis method was done. Evaluation of literature indicates that Multi Criteria Decision Making (MCDM) techniques have been widely used in renewable energy planning problem. The MCDM methods are classified into two categories: Multi-objective Decision Making (MODM) approach and Multi-attribute Decision Making (MADM) approach.[4]

The nature of MODM problem may be a linear or non-linear in which several objective functions are considered and optimized, subjected to a set of constraints. Whereas in MADM, each design strategy/option is associated with a set of attributes/constraint whereby various design strategies/options can be compared [05]. MODM problems are defined and solved by several alternative optimization models, such as compromising programming, constraint method, goal programming, and fuzzy multi-objective programming [06]. For MADM problems, the utility function method tradeoff analysis method and analytical hierarchy process method can be used [07,08]. From literature it implies that when the criteria can be quantified goal programming is the most appropriate technique to resolve MODM problem and AHP is best preferred method for solving MADM problem when the criteria are qualitative in nature. By keeping this view it's a maiden attempt of the author to identify the best energy option (Scenario) through AHP.

II. ABOUT ANALYTIC HIERARCHY PROCESS

Analytic Hierarchy Process (AHP) is a method to derive ratio scales from paired comparisons. The input can be quantitative obtained from actual measurement such as price, weight etc., or from subjective opinion such as satisfaction feelings and preference. Because of human intervention AHP allow some small inconsistency in judgment. The following steps are involved in analytic hierarchy process.

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- ✓ Identify the area of problem
- ✓ Collect and arrange the information in systematic manner.
- ✓ Define and develop the problem.
- ✓ Develop the hierarchy structure showing the intermediate level. First level of the structure, indicate the Objective / Goal of the decision problem. Next level will be criteria and sub-criteria. The last level indicates the set of options.
- ✓ After developing structure next phase is to compare each element in higher level with immediately below level element
- ✓ For comparison we need an analytic hierarchy scale to measure importance/dominance value of one element with other. Table 2 exhibits the scale.

Table: 2 - Hierarchy Scale [07]

Scale Value	Importance Level
1	Equal importance
2	Between Equal & Moderate
3	Moderate
4	Between Moderate & Strong
5	Strong
6	Between Strong & Very Strong
7	Very Strong
8	Between Very Strong & Extreme
9	Extreme

III. METHODOLOGY:

After the preliminary investigations Daryapur Tahsil of Amravati district, Maharashtra state (INDIA) is identified as a study region for the design of Integrated Renewable Energy Planning [09].

The detailed energy survey was conducted in selected region, consisting mainly of secondary and primary data. The secondary data such as landholding, demography, livestock population, occupational and infrastructural facilities was collected from respective government offices and used to prepare framework for the primary survey. The energy needs were estimated for various household end-uses such as cooking, heating, cooling, lighting & appliances.

Six different scenarios are developed by considering alternative priorities to the objective functions. 1) Business as Usual Scenario is subdivided into two sub-scenarios i.e. 1) Business as Usual No Priority Scenario2) Business as Usual Equal Priority Scenario 3) Economic Objective Scenario 4) Security-Acceptance Scenario 5) Cost-Employment Generation Scenario 6) Efficiency Scenario.

Further these six scenarios are sub divided into seven sub scenario. The developed scenarios are evaluated on the basis of associated cost emissions and employment and optimal scenario is suggested for implementation.

3.1: OBJECTIVE/GOAL:-

The objective of the define problem is to identify the best energy scenario out of selected thirteen scenarios. Three decisive factors i.e. Economics, Environment, and Social are considered in the designed problem. Cost of energy is the considered element under economic factor. Emission (COx, SOx, and NOx) is the element under environmental factor. The social factor in which employment potential is considered as element which is used to measure the impact of energy systems on human well-being [10]. Table 3 shows the selected evaluation criteria for energy planning

Table: 3 - Decisive factor & its element

Decisive factor	Element
Economical	Cost of Energy
Environmental	Emission (COx, SOx, NOx)
Social	Employment Potential

3.2: Decompose the Decision Problem into A Hierarchy:-

After defining problem the second phase is to decompose the problem in to hierarchy. Figure 1 represents the hierarchy structure for defined problem. The first level of the structure is the Focus / Goal. In the present decision making problem goal is to select best energy scenario. The second level of hierarchy structure represent decisive factors i.e. criteria. The criteria considered are Economic (Ec), Environment (Ev) and Social (So). The third level is of subdividing the criteria further into sub-criteria. The final level of the structure represents the options, which are the different energy scenarios i.e. Business as usual Equal Priority (BAUEP), Business as Usual No Priority – 1 (BAUNP1), Business as Usual No Priority – 2 (BAUNP2), Business as Usual No Priority – 3 (BAUNP3), Economic Objective Scenario–1 (EOS1), Economic Objective Scenario–2 (EOS2), Economic Objective Scenario–3 (EOS 3), Cost Employment Generation Scenario (CEGS), Security Acceptance Scenario – 1 (SAS1), Security Acceptance Scenario–2 (SAS2), Security Acceptance Scenario- 3 (SAS3), Efficiency Scenario-1 (ES1) and Efficiency Scenario- 2 (ES2) from among which one or a few have to be chosen.

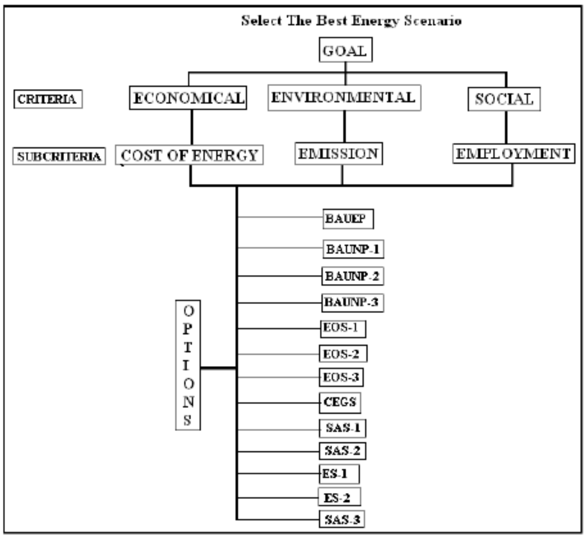

Figure: 1 - Hierarchical Structure

3.3: Establishing Priorities:-

The second stage of analysis is to provide the priority for the comparison of criteria (i.e. Economics, Environmental & Social) and sub-criteria (i.e. cost, emission and employment potential). According to literature review it is suggested that for selecting the best energy scenario economical aspect of the energy should be given the higher priority than-after environmental aspect and social aspect should be given consideration.

The priority used in analytical hierarchy process analysis (AHP) for pair-wise comparison of main criteria based on the same judgment suggested by literature review of the present study. The priorities which are used in quantitative analysis by WINQSB, the same used in pair-wise comparison of sub criteria to determine the importance values for alternatives.

1. Priorities of the three criteria with respect to overall goal.
2. Priorities of the thirteen scenarios related to cost sub criterion.
3. Priorities of the thirteen scenarios with respect to emission sub criterion.
4. Priorities of the thirteen scenarios with respect to employment potential.

In the AHP method consistency of matrix is very important. If the matrix is inconsistent, evaluation must be made until consistency is achieved. As per the literature review the consistency ratio (CR) should be lesser than 0.2 [11, 12]. The CR in the present study varied in between 0 to 0.2

3.4: Obtaining The Judgmental Matrix:-

In this three evaluation criteria were taken into consideration. The priorities were provided to the evaluation criteria on the basis of literature review with respect to each other to determine the weights of judgmental matrix. Table 4 shows the priorities of pair-wise comparison of decisive factor matrix.

Table: 4 Decisive factor Priorities

Scenarios	Economic	Environment	Social
Economic	1	3	2
Environment	0.33	1	2
Social	0.5	0.5	1

Table 5 to 8 shows the no of iteration required for achieving up to the final score of main criteria with the objective.

Table: 5 – Iteration One of Main Criteria

Scenarios	Economic	Environment	Social	Row Sum	Row Avg.
Economic	2.99	7	10	19.99	0.5558182
Environment	1.66	2.99	4.66	9.31	0.2588628
Social	1.165	2.5	3	6.665	0.1853191
				35.965	1

Table: 6 – Iteration Two of Main Criteria

Scenarios	Economic	Environment	Social	Row Sum	Row Avg.
Economic	32.2101	66.86	92.52	191.5901	0.5470445
Environment	15.3557	32.2101	44.5134	92.0792	0.2629124
Social	11.12835	23.13	32.3	66.55835	0.1900431
				350.22765	1

Table: 7 – Iteration Three of Main Criteria

Scenarios	Economic	Environment	Social	Row Sum	Row Avg
Economic	3093.7676	6447.122172	8944.640	18485.53	0.5474
Environment	1484.578	3093.767586	4292.273	8870.6188	0.2627
Social	1073.0683	2236.160094	3102.479	6411.7083	0.1899
				33767.857	1

Table: 8 – Final Iteration of Main Criteria

Scenarios	Economic	Environment	Social	Row Sum	Row Avg.
Economic	28740864	59893443.06	83096015	171730322	0.5474
Environment	13791781	28740863.51	39875003	82407647	0.2627
Social	9968750.8	20774003.83	28821802	59564556	0.1899
				313702526	1.0000

3.5.: Aggregation of Local Priorities:-

After determining the local priorities of decisive factors and its element at different level it acts as outline for aggregation. Further these local priorities are aggregated to find final priorities of the options available. The weights of the final priorities represent the rating of available options in achieving the goal of the problem. For aggregation, the following principle of hierarchic composition is used [07].

Final priority of Scenario = S1=∑ (Local priority of S1 with respect to C_i * Local priority of C_i with respect to the goal)

IV. RESULT & DISCUSSION

4.1: Scenario Allocation by AHP:-

Table 9 shows the final score of AHP analysis of main criteria. The calculated weight shows that economical aspect appears to be the most important criteria with 54.74% score. The social criteria seem to be least significance. The moderate criterion with 26.27% weight is environmental criteria.

Table: 9 – Final Weights of Main Criteria

CRITERIA	WEIGHTS
Economics	0.5474
Environment	0.2627
Social	0.1899

From figure 2 it is observed that Cost Employment Generation Scenario is on top priority with 35.39% score value on rank one. Business as Usual Equal Priority Scenario 3 is on second rank with 21.22% score. EOS 2 & 3 is on third rank with score 10.54% and Business as Usual Equal Priority Scenario 1 & 2 is on fourth rank with score 5.28%. Other alternative scenarios as per descending order are Security Acceptance Scenario 1, Business as Usual No Priority Scenario, Security Acceptance Scenario 2, Security Acceptance Scenario 3, Economic Objective Scenario1, Efficiency Scenario 2 and Efficiency Scenario 1.

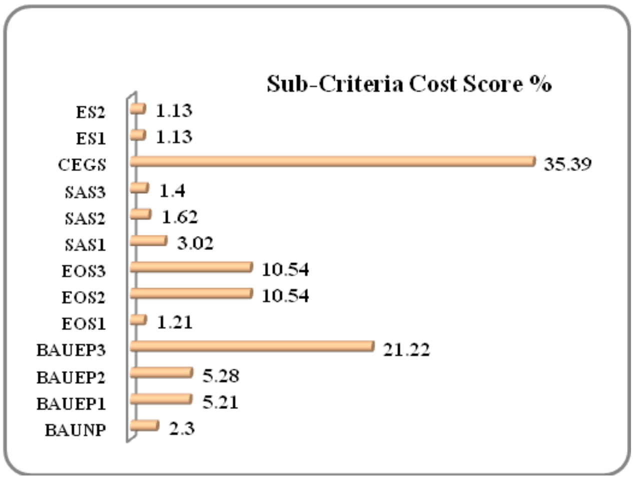

Fig.: 2 - Energy Scenario Allocation for Cost Sub-Criteria

From figure 3 it seems that Business as Usual Equal Priority Scenario 2 & 3 is on top priority with 21.91% score value on rank one. Cost Employment Generation Scenario is on second rank with 15.58% score.

Other alternative scenarios as per descending order are BAUEP – 3, SAS – 1,ES – 1, Es – 2, SAS – 3, EOS – 1, EOS – 2, EOS- 3, and BAUNP scenario.

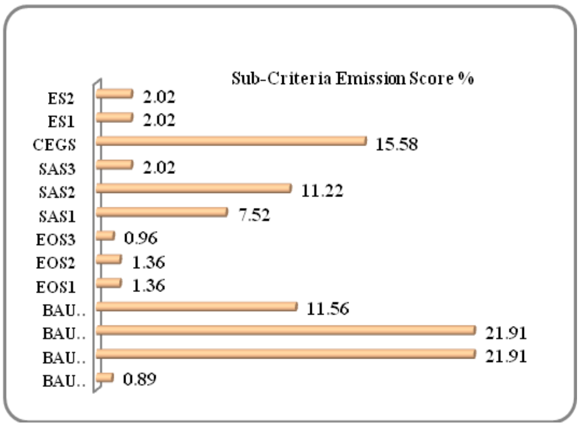

Fig.: 3 - Energy Scenario Allocation for Emission Sub-Criteria

From figure 4 it seems that Business as Usual No Priority Scenario (BAUNP) is on top priority with 37.06% score value on rank one. Economic Objective Scenario 1 (EOS-1) is on second rank with 20.79% score and with 13.54% score Security Acceptance Scenario 1 (SAS-1) is on third rank. Business as usual Equal Priority Scenario (BAUEP) 1, 2, 3 is on rank of four with score 3.92%. Economic Objective Scenario 2, 3, Cost Employment Generation Scenario is on common rank of five with score 3.88%. Other alternative scenarios as per descending order are SAS–3, ES–1, Es–2, and SAS– 2.

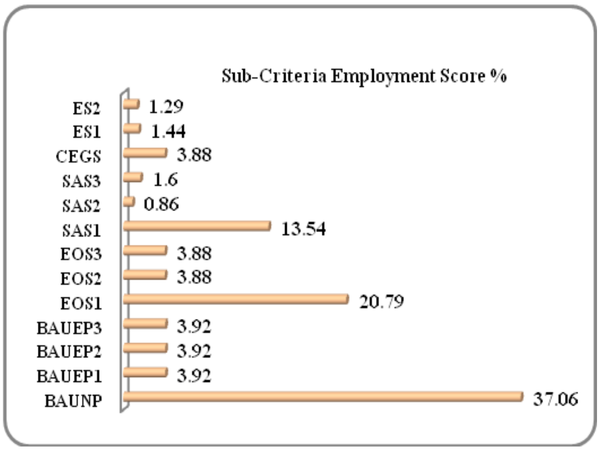

Fig.: 4 - Energy Scenario Allocation for Employment Sub-Criteria

Table 10 present the determined rank for the thirteen alternatives scenarios dealt with pair-wise comparison of cost of energy, emission and employment sub-criteria

Table: 10 – Ranking of Cost, Emission & Employment sub criteria

	Cost Sub-criteria	Emission Sub-criteria	Employment Sub-criteria
Scenario	**Rank**	**Rank**	**Rank**
BAUNP	6	7	1
BAUEP1	4	1	4
BAUEP2	4	1	4
BAUEP3	2	3	4
EOS1	10	6	2
EOS2	3	8	4
EOS3	3	9	4
SAS1	5	2	3
SAS2	7	4	7
SAS3	8	5	5
CEGS	1	1	4
ES1	9	5	5
ES2	9	5	6

Fig. 5 represents the variation in percentage score when pair wise comparison of different options with sub-criteria i. e. cost of energy, emission and employment. From figure it appears that Cost Employment Generation Scenario (CEGS) is on top priority with 35.39% score value on rank one. Business as Usual Equal Priority Scenario 3 is on second rank with 21.22% score. Economic Objective Scenario (EOS) 2 & 3 is on third rank with score 10.54% and Business as Usual Equal Priority Scenario (BAUEP) 1 & 2 is on fourth rank with score 5.28%. Other alternative scenarios as per descending order are Security Acceptance Scenario 1 (SAS-1), Business as Usual No Priority Scenario (BAUNP), Security Acceptance Scenario 2 (SAS-2), Security Acceptance Scenario 3 (SAS-3), Economic Objective Scenario1 (EOS-1), Efficiency Scenario 2 (ES-2) and Efficiency Scenario 1 (ES-1) Energy scenario allocation obtained by AHP analysis for emission sub-criteria shows that Business as Usual Equal Priority Scenario (BAUEP) 1 & 2 is on top priority with 21.91% score value on rank one. Cost Employment Generation Scenario (CEGS) is on second rank with 15.58% score. Other alternative scenarios as per descending order are BAUEP-3, SAS-1, ES-1, ES-2, SAS-3, EOS-1, EOS-2, EOS-3, and BAUNP scenario. Energy scenario allocation obtained for comparison of employment sub-criteria indicates Business as Usual No Priority Scenario (BAUNP) is on top priority with 37.06% score value on rank one. Economic Objective Scenario 1 (EOS-1) is on second rank with 20.79% score and with 13.54% score Security Acceptance Scenario 1 (SAS-1) is on third rank. Business as usual Equal Priority Scenario (BAUEP) 1, 2, 3 is on rank of four with score 3.92%. Economic Objective Scenario 2, 3, Cost Employment Generation Scenario is on common rank of five with score 3.88%. Other alternative scenarios as per descending order are SAS–3, ES–1, Es–2, and SAS– 2.

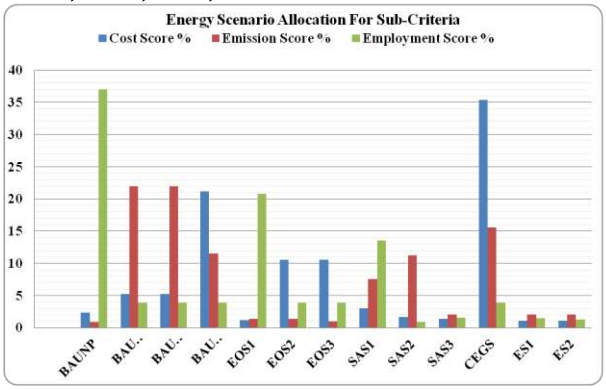

Fig. 5 - Energy Scenario Allocation for Cost, Emission & Employment Sub-Criteria

From Fig. 6 it implies that "Cost Employment Generation Scenario (CEGS)" seems to be the best scenario. The position of other scenario is as BAUEP-3, BAUEP-2, BAUEP-1, BAUNP, EOS-2, EOS-3, SAS-1, EOS-1, SAS-2, SAS-3, ES-1 AND ES-2. The evaluation of decisive factors indicates that economical aspects are more important in renewable energy scenario selection problem.

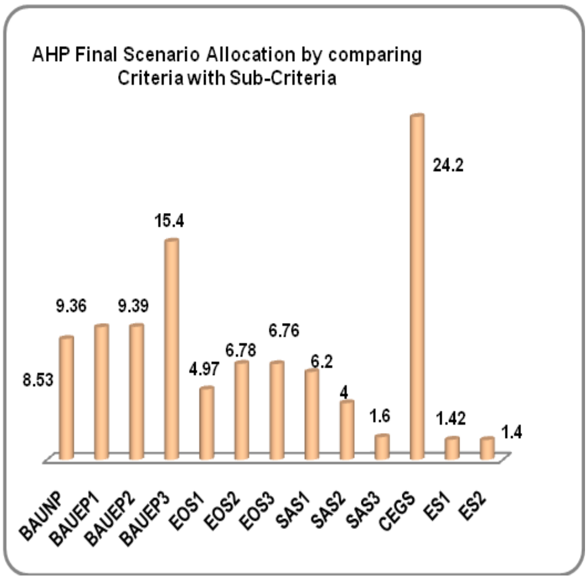

Fig. 6 - Final Renewable Energy Scenario Allocation by AHP

4.2: Scenario Allocation by MODM Method:-

The multi-objective goal programming mathematical model is developed to find the solution of different developed scenarios and their assign priority. The developed model is solved by using WINQSB package. Daryapur Block has 74 Panchayats (GPs) and 150 villages out of which 133 villages are in existence and 17 villages are migrated in past few years (Census of India 2011). Table 12 present the summary of energy resources allocation at Daryapur Block level for base year & year 2025. The developed scenarios are evaluated on the basis of cost of energy involved in it, emission generated through utilizing the allotted resources, employment creation through implementing the technology required for different resource, & use of local resources.

Table 12: Optimal Resource Allocation for Daryapur block

Scenario	Domestic Activities				
	Cooking	Lighting	Heating	Cooling	Appliances
PECS	Biomass 69.5% Dung cake 8% Kerosene 2.5% LPG 20%	Grid electricity 80% PV 3% Kerosene 17%	Biomass 79.2% Dung cake 13.7% Kerosene 7.1%	Grid electricity 100%	Grid electricity 100%
BAUNP	Dung Cake 1.43% Biomass 59.83% Biogas 20.13% S. Thermal 18.61%	Biogas electricity 100%	Solar Thermal 100%	PV electricity 100%	PV electricity 100%
BAUEP - 1	S. Thermal 18.6% PV elect. 81.4%	PV electricity 100%	Solar Thermal 100%	PV electricity 100%	PV electricity 100%
BAUEP - 2	S. Thermal 18.6% PV elect. 81.4%	PV electricity 100%	Solar Thermal 100%	PV electricity 100%	PV electricity 100%
BAUEP - 3	S. Thermal 18.61% PV elect. 81.39%	PV electricity 100%	Solar Thermal 100%	Diesel electricity 100%	Diesel electricity 100%
EOS - 1	LPG 100%	Kerosene 100%	Biogas 59.15% S. Thermal 40.85%	PV elect. 73.5% Grid elect. 26.5%	Grid elect. 100%
EOS - 2	S. Thermal 18.61% Diesel elect. 81.39%	Diesel elect. 100%	Diesel elect. 100%	Diesel elect. 100%	Diesel electricity 100%
EOS - 3	S. Thermal 0.1% Diesel elect. 99.1%	Diesel elect. 100%	Diesel electricity 100%	Diesel elect. 100%	Diesel electricity 100%
SAS - 1	Dung Cake 1.4% Biomass 80% S.. Thermal 18.6%	PV electricity 100%	Biogas 59.15% Solar Thermal 40.85%	PV electricity 100%	PV electricity 100%
SAS - 2	Dung Cake 1.4% LPG 98.6%	Kerosene 100%	Solar Thermal 100%	PV electricity 100%	PV electricity 100%
SAS - 3	LPG 100%	Kerosene 100%	Biogas 59.2% S. Thermal 40.8%	PV electricity 100%	PV electricity 100%
CEGS	Solar Thermal 18.6% PV. Elect. 81.4%	PV electricity 100%	Solar Thermal 100%	PV electricity 100%	PV electricity 100%
ES - 1	LPG 100%	Kerosene 100%	Biogas 59.2% S. Thermal 40.8%	PV electricity 100%	PV electricity 100%
ES - 2	LPG 100%	Kerosene 100%	Biogas 59.2% S. Thermal 40.8%	PV electricity 100%	PV electricity 100%

Table 13 and Fig. 4 show the abstract obtained by solving multi-objective goal programming model in WINQSB package.

Table 13: Scenario Outcome for-Base Year 2017-18

Scenario	CASE	Priority Level	Total cost incurred (million $/year)	Emissions (Tons/year)		
				COx	SOx	NOx,
PECS	1	Actual as per surveyed data	1.30	28588.4	43.72	148.4
BAUNP	1	No Priority	1.91	57.71	6826.3	1210.8
BAUEP	1	1-Emission 2-Economics 3-Scecurity Acceptance	0.94	0	0	0
	2	1-Economics 2-Emission 3-Scecurity Acceptance	0.24	0	0	0

	3	1-Economics 2-Scecurity Acceptance 3-Emission	0.24	2271.5	31.3	2.75
EOS	**1**	1-Cost 2-Employment Generation 3-Efficiency 4- Other objective	2.55	6498.69	343.47	0
	2	1-Employment Generation 2-Cost 3-Efficiency 4- Other objective	0.82	12646.5	193.08	17.05
	3	1-Employment Generation 2-Efficiency 3-Cost 4-Other objective	0.82	14169.9	213.95	18.9
SAS	**1**	1-Petroleum Product 2-Local Resources 3-Social Acceptance 4- Other objective function	1.32	969.67	214.93	30.16
	2	1-Local Resources 2-Petroleum Product 3-Social Acceptance 4-Other objective function	2.48	4517.65	124.96	0
	3	1-Social Acceptance 2-Local Resources 3-Petroleum Product 4- Other objective function	2.49	5553.03	338.96	0
CEGS	**1**	1- Cost & Employment Generation 2- Other objective function	0.17	0	0	0
ES	**1**	1-System Efficiency 2- Other objective function	2.49	5553.03	338.96	0
		1-System Efficiency 25% increase 2- Other objective function	2.49	5553.03	338.96	0
Economic Objective :- Cost, System efficiency, Employment generation						
Security Acceptance:- Petroleum Product, Local Resources, Social Acceptance						
Emission:- COx, SOx, NOx						

By comparing various scenarios with each other on the basis of cost, emission and employment it is observed that current energy consumption cost can be reduce by implementing Cost Employment Generation Scenario (CEGS) or by implementing Case 3 of BAUEP scenario or case 2 of Economic Objective Scenario. Out of these scenarios, CEGS scenario is to be implemented due to the use of PV electricity and solar thermal for cooking & heating activities which are local resources. CEGS Scenario shows that, for lighting, cooling and other domestic electrical appliances PV electricity is the best option hence it should be augmented; This scenario results in cost reduction by many folds of present cost of energy and 100% reduction in COx, SOx and NOx, respectively. Due to the use of local energy resources, this scenario will satisfy the goal of employment generation at the reduction of environment emissions.

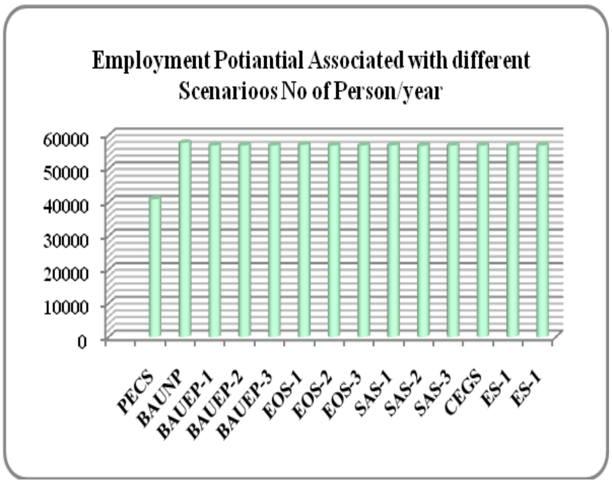

Fig. 4 - Annual Employment Potential Associated in different Scenario

V. CONCLUSION

Extensive literature survey has been carried out to know the multi criteria evaluation framework for the generated scenario. Various assessment techniques have been studied with their application to a large verity of problems in energy planning.

AHP has been found best suitable & widely used method for the ranking of renewable scenario. Initially thirteen scenarios were taken into consideration for evaluation. Final ranking of the scenarios is made on the decision indicates. The conclusions resulting from the present study have been discussed below [13].

The findings of AHP analysis propose that the Cost Employment Generation Scenario (CEGS) is the best energy scenario alternative. The evaluation of main criteria point out that economical factor is more important in scenario allocation problem.

1. Analysis of weightings of main criteria revels that economical is the most important criteria with 54.74% score. The least significance criteria is social. The moderate criterion with 26.27% weight is environmental criteria.
2. Evaluation by priority using AHP has ranked Cost Employment Generation Scenario (CEGS) on top position amongst the thirteen scenarios available.
3. Evaluation by priority using AHP has ranked Business As Usual Equal Priority Case - 3 Scenario (BAEP-3) on second position amongst the scenarios considered. AHP has ranked Efficiency Scenario Case – 2 (ES-2) lowest in the list of scenarios.
4. The energy scenario allocation obtained by WINQSB and AHP is almost similar for main criteria and sub criteria.

REFERENCES

1. Ozgur, M.A., (2013) “Review of Turkey’s Renewable Energy Potential, Renewable Energy”, Vol. 33, pp. 2345-2356.
2. Zadeh, L. (1965), Fuzzy sets, Information Control, 8, 338-353.
3. Mahdi Saeedpoor, Amin Vafadarnikjoo, (2010) “Multi-criteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology the case of Istanbul”, Energy. 35(6), pp: 2517-2527

4. Evangelos Triantaphyllou et al. (1998) “Multi-criteria decision making: an operations research approach” Journal Encyclopedia of electrical and electronics engineering Volume 15 pp: 175-186
5. J. P. Huang et al., (1995) “Decision Analysis in Energy & Environment Modeling”. Energy (20) 9, pp. 843-855
6. Zhu and Chow, (1997) A review of Emerging Technique on Generation Expansion Planning [j] IEEE Trans on Power Systems, 12 (4), pp: 1722-1788.
7. T. L. Saaty. The Analytic Hierarchy Process, Planning, Piority Setting, Resource Allocation. USA: McGraw-Hill International Book Company, New York, 1980.
8. Saaty, T .L. & Kearns K. (1985) Analytical Planning; The Organization of Systems, Oxford: Pergamon Press.
9. Samir J. Deshmukh et. al. (2014) “DSS for rural domestic energy planning – case study of a block in central India” International Journal of Energy Sector Management Vol. 8 No. 1, 2014 pp. 27-55
10. United Nations Department of Economic and Social Affairs (UNDESA) Division for Sustainable Development: Energy Indicators for Sustainable Development: Country Studies on Brazil, Cuba, Lithuania, Mexico, Russian Federation, Slovakia and Thailand, (2007), http://www.un.org/esa/sustdev/publications/energy_indicators (11.02.2013).
11. Soma, K., (2003) How to involve stakeholders in fisheries management—a country case study in Trinidad and Tobago. Marine Policy, 27, pp: 47-58.
12. Habibe Yelda Şener., (2014) “ Determining New Markets Using Analytic Hierarchy Process: Case Study in Güral Porcelain,” International Journal of Marketing Studies; Vol. 6, No. 5;
13. Kaya, T. and Kahraman C. (2010), Multi-criteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul, Energy 35, 2517-2527

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