

Selection of Appropriate Renewable Energy Resources for Uttar Pradesh by using Analytical Hierarchy Process (AHP)

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ABSTRACT: In this modern era, energy became a necessary product in order to have a good quality of life, human development and economic growth. The energy consumption depends on the fossils fuels which are limited and have various adverse impacts on the environment. Depending on this issue, renewable energies become crucial alternative energies in order to provide clean and sustainable energy, clean surroundings and to care for the economy. Accordingly, the priorities of the renewable energies are appraised in this study to find out best alternative renewable energy resource for Uttar Pradesh energy sector. AHP model is selected as a methodology for this study which gives the flexibility for the survey needed researches. In AHP model following four criteria are selected and which are technical, economic, social and environmental. In this AHP model 8 sub criteria's of maturity, efficiency, technical cost, operational cost, public acceptance, job creation, availability of renewable energy and geographical condition has been considered. In this study three renewable energies are considered which are solar energy, biomass, and wind energy. Solar Energy is observed as the best Energy alternative in Uttar Pradesh. Furthermore, it is purposed that depending on the results and the precedence of the renewable energy, the decision makers can get advantage from this study in order to develop long-run policy for economic issues with respect to energy sector and create a roadmap for the energy efficiency policy for the state.

KEYWORDS: Renewable energy, Uttar Pradesh, Analytical Hierarchy Process (AHP).

I. INTRODUCTION

Energy is one of the most important concerns for all countries hence in order to achieve environmental, economic and technological aims, it is important for the countries to be efficient in production and supply of energy. Energy has turn into a critical element for sustainable growth and wellbeing of every country in present period. The World Energy meeting has predicted that fossil based oil, coal and gas assets will be exhausted in fewer than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly [1].

India's commercial energy utilization has been increasing rapidly in current years keeping rapidity with high financial growth rate. India depends profoundly on coal and oil to fulfill its energy demand. The shares of various energy sources in primary non renewable energy utilization in 2005 were: coal 55.0%; oil – 29.9%; natural gas – 8.5%; hydroelectricity – 5.6%; and Nuclear energy – 1.0% [2]. This trend of energy utilization is extremely challenging for the country. Coal is a polluting fuel and is the principal reason for Green House Gas (GHG) production; its exploit requirements to be shortened for sinking emission of mutually greenhouse gases and local air pollutants. India depends

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greatly on import for fulfill its domestic oil necessities; imports accounted for 72% of India's entirety oil utilization in 2004–2005 [2].

Energy expenditure of India is therefore estimated to continue increasing extensively in the future. The single realistic option for enhancing energy security and dropping coal expenditure as well as oil import bill would be improving inefficiency of energy utilize and promoting renewable energy.

Energy is necessary for economic growth in the entire sector of Indian economy. It is thus compulsory for India to quickly come across towards latest and rising renewable energy technologies and usage of energy efficient technologies and as well as execute energy preservation laws. The country immediately desires to build up a sustainable path of energy growth. Promotion of energy preservation and increased exploit of renewable energy source are the double planks of a sustainable energy supply. Opportunely, India is blessed with a combination of renewable energy resource, like biomass, the solar, wind, geothermal and small hydropower and implementing one of the world's biggest program in renewable energy.

India is committed to become one of the world's chief clean energy producers. The Government of India has already completed a number of requirements, and recognized lots of agencies that will assist it to reach its target.

Energy scenario in Uttar Pradesh: Uttar Pradesh is surrounded by Nepal on the North, Himachal Pradesh on the northwest and Haryana on the west, Rajasthan on the south-west, Madhya Pradesh on the south and south-west and Bihar on the east. Uttar Pradesh Situated between 23° 52' N and 31° 28' N latitudes and 77° 3' and 84° 39'E longitudes, Uttar Pradesh is the fourth largest state in the country. Uttar Pradesh is now divided into seventy-one districts under eighteen divisions [3]. Uttar Pradesh habitually experience power crises as demand for electricity repeatedly exceeds supply considerably. More the last 20 years power deficiency has remained within the range of 10-15%, while shortages in periods of peak demand reach at even higher levels. In 2013, even a gap of up to 43% opens up between the state's demand and supply of electricity. This results in poor and unreliable power supply with rampant power cuts and prolonged periods of low voltage. As a consequence, industrial investment in Uttar Pradesh has been constrained, with industries preferring to locate themselves elsewhere [4].

Efficient energy generation is critical issue as it contributes towards the productivity of households and increased income. Energy demand has been increasing steadily along with the development of the state. In view of limited conventional energy resources and their limited exploitation, concern on increasing environmental pollution all these factors have caught focus on production of energy based on new and renewable energy sources which are now given high priority and promotion. Renewable energy systems ensures availability of sufficient power, upliftment in living standards, gives boost to industrial sector of particular region thus resulting in generation of career opportunities, resolving environmental issues, and minimizing human migration towards other states[5].

Each type of Renewable Energy has its advantages and disadvantages. Due to difficulty in selecting the optimal option amongst various alternatives, a powerful multi-criteria decision analysis model is needed. The Analytic Hierarchy Process (AHP) a MCDM model introduced by Thomas Saaty, is an effective tool for dealing with such complex decision making problems and may support the decision maker to set priorities and make the accurate decision. The AHP helps to capture both subjective and objective aspects of a decision by sinking complex decisions to a series of pair-wise comparisons and then synthesizing the results. The essence of AHP is that it simplifies a complex decision by decomposing the problem into a hierarchy of 'criteria' or sub-problems which are further analyzed individually. The purpose of this research is to select appropriate renewable energy resource for Uttar Pradesh energy sector by the AHP method.

II. AHP IN ENERGY PLANNING

Analytic Hierarchy Process (AHP) techniques are gaining popularity in sustainable energy management. The techniques provide solution to the problems involving conflicts and multiple objectives. There are various studies performed using AHP in energy sector. I.-S. Antonopoulos et al. (2014) reveals that AHP is used for the Ranking municipal solid waste treatment and the evaluation of waste treatment. In this study sensitivity analysis is also performed [6]. J.R. San Cristóbal (2010) used AHP for the selection of a Renewable Energy project corresponding to the Renewable Energy Plan launched by the Spanish Government [7]. Salman Ahmad et al. (2013) used AHP for

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Selection of renewable energy sources for sustainable development of electricity generation or production in Malaysia. AHP can serve decision makers to formulate long-term energy policy aiming for sustainability [8]. In the research of Sunil Luthra et al.(2014) an attempt has been made to identify and rank the major barriers in the adoption of ‘renewable and green’ energy technologies in the Indian context with the help of AHP [9]. JingzhengRen et al. 2014 selected five low-carbon energy sources—hydro, wind, biomass, solar, and nuclear were the most promising options for China using Analytic Hierarchy Process (AHP) [10].

III. METHODOLOGY

1. Multi-Criteria Decision Making Method

By using qualitative and quantitative data, Multi-criteria decision-making method (MCDM) tries to solve the dilemma. It creates choices among alternatives with respect to the specific targets and measurable criteria. This method is mostly used in research fields for selecting the best for the dilemma, which involves arguments and multiple targets [11]. However, it is well known that the more incompatible the targets are, the more complex the problems. Besides, compatible objectives lead to difficulties in making decisions. In selecting the best opportunity, MCDM method can be used for ranking and regulating the alternatives order from the most preferable to the least preferable. Hence, based on uncertain conditions, MCDM method is used by the researcher to make suitable decisions about the most appropriate choice [12]. Saaty (1980) recommended that there are some sub-methods under the MCDM method which can be used to analyze complex problems. Among the sub-methods, Analytical Hierarchy Process (AHP) happens to be the most used and best-known method in analyzing situations and problems that contain multiple and controversial targets. This technique helps authors to comprehensively analyze the situation and also structure the decision problem.

2. Analytical Hierarchy Process (AHP)

Thomas L. Saaty investigated AHP model in 1980s. It is very useful for the decision maker in order to solve the problems and rank the best alternative in order to reach the best decision [13].

In this work, Analytical Hierarchy Process method is used for evaluating the appropriate renewable energy potentials used for electricity generation in selected Uttar Pradesh. Additionally, in order to reach this goal four major criteria’s were provided to make an unsuspecting decision to policy makers and presented as technical, economical, social, ecological & geographical. Moreover, sub-criteria were set for each criterion and used for certain decisions on ranking renewable energy sources. From technical perspective maturity, plant & equipment efficiency were set as a sub-criteria, for economic issue technical cost and operation cost were taken under consideration for social issue public acceptance with quality of life and job creation were evaluated as a sub-criteria, for ecological & geographical issue availability of renewable energy and geographical conditions were taken under evaluation as a sub-criteria. Thus Eigenvector was used as a method for this study as a way of evaluating AHP model.

Key steps involved in this methodology are:

1. Develop structure of the hierarchy
2. Make pair-wise comparison and compare factors on hierarchy
3. Derive priority vector
4. Calculate consistency of the predilection
5. Get the alternative’s comprehensive priorities

Since the pair-wise comparison can be very subjective. AHP uses a consistency check of comparisons, equation 1 & 2 show how CI and CR are calculated respectively.

$$CI = \frac{\lambda_{max} - 1}{n - 1} \dots \dots \dots (1)$$

Where, CI is consistency index
 λ_{max} is maximum Eigen value of comparison matrix,
n is the number of elements in the comparison.

$$CR = \frac{CI}{RI} \dots \dots \dots (2)$$

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Where, CR is consistency Ratio,
RI is a random index.

Random index values for different sizes of the matrices are given in below table

Table: 1 RI values for different sizes of a matrix, n [14]

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10
Random Index Values	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

A consistency test helps to evaluate judgments made in pair-wise comparison. In case of a failure, pair-wise comparisons are made again. A CR of less than 0.1 is recommended whereas, for a value greater than 0.1, no meaningful results can be obtained.

3. AHP Structure for Renewable energy selection:

In this study a multi-criteria model is developed to analysis a particular renewable resource for electricity production in Uttar Pradesh. The four main criteria and eight sub-criteria have been identified. To further enrich the model, eight sub-criteria have been identified having a direct influence on ranking renewable sources; the goal of the decision problem. The criteria and sub-criteria are also supported by the literature.

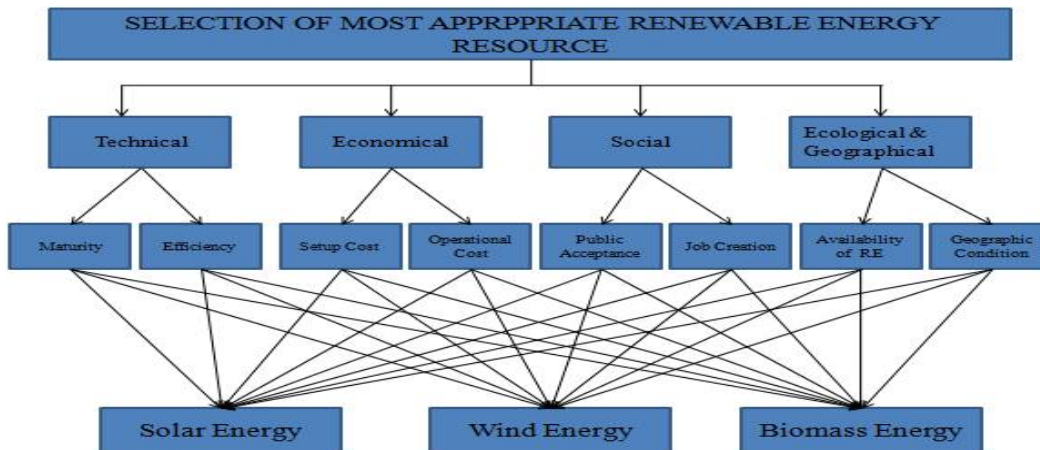


Fig: 1 Proposed AHP model

The AHP model formulated in this study consists of four levels. At the top level is the goal of the model followed by the criteria at level two. Sub-criteria are at level three while various renewable sources are at the fourth level, named, alternatives. In this study four criteria are technical, Economic, social, Ecological & Geographical at second level. Sub-criteria are at the level three and these are as follows maturity, efficiency, setup cost, operational cost, public acceptance, job creation, availability of Renewable energies and geographical conditions. At the fourth level various alternatives are solar energy, wind energy and biomass. The structure of model is depicted in Fig. The pair wise comparisons are made by using the fundamental scale of the AHP.

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Table: 2 Saaty Scale of the AHP [14]

Intensity of Important	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extremely Importance
2,4,6,8	Used to express intermediate values

The matrix entries indicate the mathematical weight of each element with the other element in assessment. A 9 point scale is used to transform qualitative information into numerical values. The scale is explained in table.

IV. RESULTS AND DISCUSSION

Owing to complexity in selecting the most favorable option amongst various renewable resources, this study used eight sub-criteria in four categories to assess three alternatives for electricity production. At every level of the model, a pair-wise comparison matrix is developed.

Various matrixes are drawn for comparison of the criterion with respect to the goal, comparison of sub-criterion with respect to criterion and comparison of the alternatives with respect to the sub-criterion.

For each comparison matrix a normalized principal eigenvector of the matrix is computed. This vector is called a priority vector. A priority vector signifies the importance of each element with respect to its parent level. Then by using Equation 1 and 2 consistency of the comparison is performed.

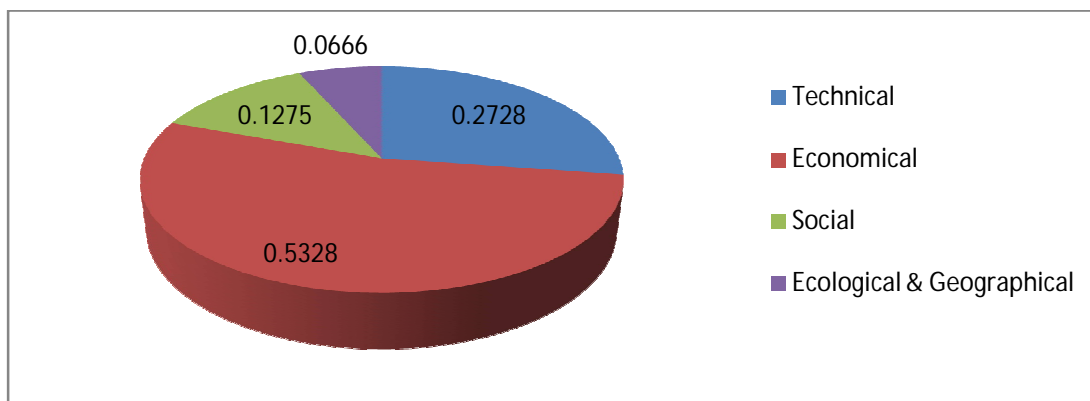


Fig: 2 Relative weights of the criteria on the basis of goal

The assessment model results indicate that Economical aspects are founded as a most crucial criterion with the priority level of 0.5328 and followed by the technical (0.2728), social (0.1275) and environmental (0.0666) aspects respectively. The relative weights of the criteria are shown in Fig.

Relative weights of sub-criteria with respect to alternatives are calculated and represents in the given fig.

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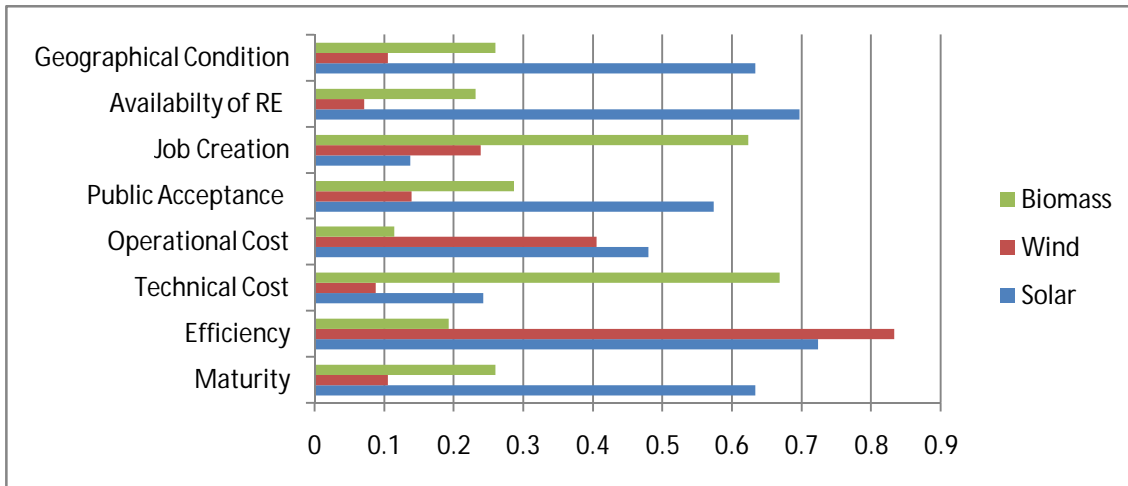


Fig: 3 Graph of the weight of sub-criteria with respect to alternatives

In this fig. all alternatives are compared with respect to the sub-criteria. Weights of the alternative are given with respect to the sub-criteria.

All the priority weight of criteria, sub-criteria and the alternatives with respect to goal are given in the table.

Table: 3 Priority Matrixes for Selecting Appropriate Renewable Energy Source in Uttar Pradesh:

Criteria weight		Sub-criteria weight		Solar	Wind	Biomass
Technical	0.2728	Maturity	0.2046	0.6333	0.1061	0.2604
		Efficiency	0.0682	0.7235	0.8330	0.19318
Economical	0.5328	Technical cost	0.1332	0.2431	0.0882	0.6686
		Operational cost	0.3996	0.4795	0.4054	0.1149
Social	0.1275	Public acceptance	0.0212	0.5736	0.1399	0.2864
		Job creation	0.1064	0.1376	0.2389	0.6234
Ecological & geographical	0.0666	Availability of R.E.	0.0110	0.6965	0.0718	0.2316
		Geographical condition	0.0554	0.6333	0.1061	0.2604
Overall priority vector weight				0.47256	0.28729	0.29072

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According to the AHP tool developed in this study solar seems to be the best renewable technology to be adopted for electricity generation followed by biomass, wind energy. The evaluation of renewable resources in an achieving goal is presented in the fig.

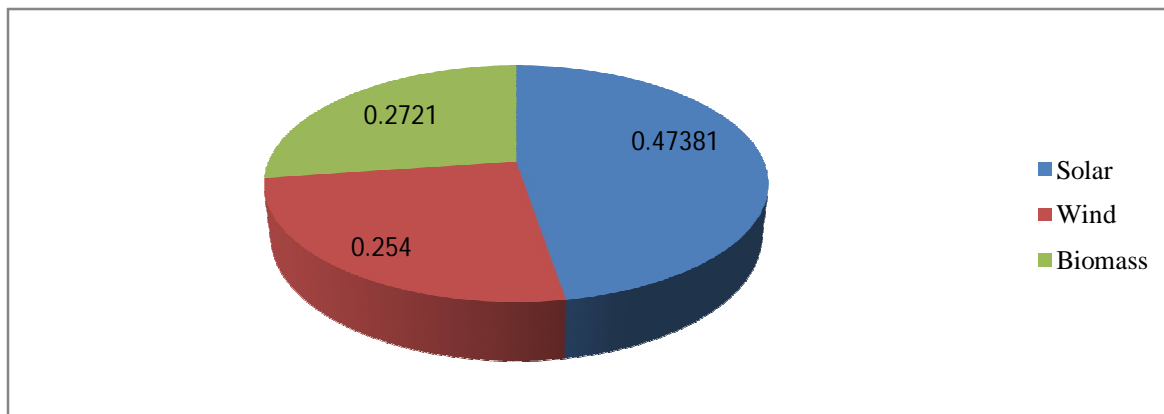


Figure: 3.3 Pie charts for renewable energy on priority basis

The Pie chart and table shows the empirical results of AHP model for Uttar Pradesh alternative renewable energy resources and it represents that depending on the criteria and sub-criteria evaluation solar energy became the most appropriate alternative energy in order to invest and provide energy to the grid with an efficient level and have a sustainable economic growth. Its priority level was measured as 0.472567 and ranked as the most appropriate alternative renewable energy out of 3 alternatives and followed by Biomass (0.290725), the wind (0.287291) respectively.

V. CONCLUSION

In this study, the major suitable renewable energy potentials are evaluated, according to various potentials. These potentials are examined to select the most appropriate energy sources in order to increase contribution to the energy sector. The potentials are evaluating by using AHP method with four main and eight sub-criteria to reach the goal. The four criteria are technical, economical, social, ecological & geographical and the eight sub-criteria are maturity, efficiency, set up cost, operational cost, public acceptance, job creation, availability of RE, geographic condition. The various alternatives are solar energy, biomass, and wind energy. The model is prepared by stated levels as a goal, criteria, sub-criteria and the alternatives and in order to have the unsuspecting result, the inconsistency ratio is considered. As a result of this work, the following conclusions are founded:

- Economic aspects are founded as a most crucial criterion with the priority level of 0.5328 and followed by the technical (0.2728), social (0.1275) and environmental (0.0666) aspects respectively.
- From the analysis of the alternative with respect to criteria and sub-criteria solar energy comes as most crucial energy source weighted as 0.4725 followed by biomass (0.2907) and wind energy (0.2872).

The result of the study may be a guideline for the authorities in shaping the energy policies and also may be good roadmaps for the environmentalists, private organizations, researchers and local public.

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