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An Empirical Evaluation of the Significant Renewable Resource in India using Multi-criteria Analysis

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***Abstract*— The multi-criteria evaluation depicts or demonstrates the potential in reducing the environmental presence by using renewable resources which play a significant role in building a sustainable future by optimalisation of renewable resources through environmental & energy analysis.**

Purpose- The identification of energy resources and the utility factors involved in electricity generation through RES is a significant area of interest. This empirical study is based on the exploration and orientation of cost, availability, responsiveness and sustainability as the predictors of RES.

Design/ Methodology/ Approach- This study primarily is based on a mix of qualitative and quantitative data sets with special reference to multi-criteria analysis and problem solving techniques. Thus, design of research belongs to primary study.

Findings- A multi-criteria analysis is very important, useful and effective technique in business research dealing with numerous factors affecting the generation of electricity through RES and other sources of energy. The results of multi-criteria analysis show the significant correlation between critical factors and sources of energy in the domain of renewable.

Practical Implications- The study would be useful for management practitioners and policy makers to understand the comprehensive view in the renewable sector as far as electricity and power is concerned. There is a significant difference and implications of present study adding value and knowledge in line of renewable resources and thus practical results are highly suitable in today's energy context and future depends on renewable energy technologies and energy management.

Originality/Value- The present research paper provides the collection, classification and comprehensive criteria's responsible for renewable sector and sustainability, which may be helpful for future researchers when learning the existing research work in domain area of research w.r.t. renewable resources using multi-criteria analysis.

***Keywords*— RES, GoI, Responsiveness, Profitability, Growth, Multi-Criteria Analysis (MCA).**

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I. Introduction

Renewable Resources & Its Importance

These days renewable resources is a topic of concern and discussion. Renewable resources is said to be green energy and is playing a very important role in day to day lives. It is a crucial factor responsible for social, industrial development and economic growth of a nation. Recent Research have highlighted energy efficient technologies, its evolution and selection (Doukas *et al.*, 2010). Many nations are looking for renewable resources strategy and its usefulness to meet a demand and supply. Renewable resources for power generation majorly include solar, micro-hydro, biomass, wind and energy from wastes (Radhakrishna and Kumar, 2008). In modern India and other developing countries are looking on various issues involved in harnessing power from the renewable resources, which further includes government policies, environmental laws, geographic location, technology adoption, generation, control, quality of power and other related issues (Lin *et al.*, 2010).

However, the development of renewable resources and green energy sector has been failed due to inappropriate selection of technology, capital & Investment, environmental laws and security concerns arising out of internal external consequences (Solanky *et al*., 1997).

This research paper has analyzed different operation of renewable resources i.e. micro-hydro, biomass, wind generation and solar PV. The critical investigation of the prime operational characteristics like efficiency, environmental impacts, cost, life-cycle etc. decides the best renewable resources based on the prioritization of the different criteria selected by an end user. The exhaustive analysis on renewable resources entails the investigation of best choice of renewable resources considering all major concerns.

There are various types of statistical analysis, tools and methodologies are available and helping taking managerial decision through qualitative and quantitative criteria's linking to the problem statement.

Many influencing criteria of renewable resources are investigated through the research scheme designed and developed by Saaty (1980) the Analytic hierarchy process. In research methodology AHP is a very important and subjective method for analyzing qualitative criteria to form a weighing of the evaluating units. The prime aim is to show an important way of improving investigation approach in various types of

complex and difficult decision problems (Saaty, 2006; Ray *et al.*, 2010).

II. Literature Review

Much research has been done on renewable energy management, but no researcher has studied the renewable resources from the performance aspects of the renewable alternatives. Generally, literature review is the section comprising different research studies conducted on a relevant context from time to time.

It reveals the following works in the area of renewable energy/resources: Singh *et al.*, (2009) and Bilharz, (2006) presented several scenarios and the future prospects of renewable resources to meet power storage problems in different parts of the world/country. Cairns (2004) and Midilli et al., (2006) and Ermis *et al.*, (2007) highlighted green accounting for evaluating the impacts attributable to nature and policy investigation for a more critical utilization of social welfare.

Anandalingam and Bose (1996) discussed several research methodologies to investigate new energy production scenarios mapping of optimal flow of energy from supply side to demand where geographical information or effective sector resources plan is incorporated. Kwak *et al.*, (2002) discussed his assessment on the impacts of the environment in regional development projects in Korea as per his study on environmental multi attribute index value.

Barin *et al.*, (2009) evaluated the working/operation of the renewable sources namely fuel cells, WG, PV cells, microturbines on behalf of various investigation parameters that supported it like lifecycle, costs, efficiency, power application range.

Criteria Definitions:

The main criteria for renewable resources development are: geographical location, political factors, climatic conditions, quantitative abundance of resources. But the identification of the most critical factors like climatic conditions play a major role in identifying renewable resources (Doukas *et al.*, 2010; Dalton *et al.*, 2009; Goyal and Jha, 2008).

Photovoltaic (PV)-

In solar PV, solar energy is directly converted into electrical energy giving out direct current (DC). This system includes batteries, mounting structure, inverter to support AC Load and PV module. Solar PV is the most efficient with no pollution emission, very less maintenance cost with an added life of 20-30 years. All these factors make solar PV the most promising renewable resources in the world, all around the globe.

Wind Generation (WG)-

Role of Wind turbine is to generate electricity. As of 31 December 2013 the installed capacity of wind power in India was 20149 MW, mainly spread across Tamil Nadu (7154 MW), Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka (2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2MW), West Bengal (1.1 MW) and other states (3.20 MW). It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2014. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power. India's wind atlas is available.

Source: MNRE, India (2013)

Figure 1. India-Wind Power Installed Capacity by Year

Fig.1 represents the projection from 2006 to 2013 as far as different MW capacity of Wind power generating capacity of India is concerned and shows the importance and added value in India's total installed capacity.

Biomass (BM)-

It is an organic matter which is derived from animals, plants etc. It can also be obtained from dung, forests wastes, cultivated crops to yield clean and combustible gases to be used as Thermal Energy or electrical energy.

Micro-hydro (MH)-

Along with all other alternative sources, micro hydro is one of the other alternative sources that contribute to the clean, eco-friendly and pollution free environment. The capital cost of a power plant is directly proportional to the capital cost of a power plant.

Capital cost includes equipment cost and installation cost including engineering costs (Kanase- Patil et al., 2010; Singh et al., 2009; Thiam, 2010). Capital cost and generation cost per kilowatt hour for various GES in India is given in Table I (Singh *et al.*, 2009; Chen *et al.*, 2010; Kahraman *et al.*, 2009; Plastow, 2001).

The main objective of this study is to find the most appropriate type of renewable resource. The parameters contributing to this are:

Reliability (R)

Consistent, constant and adequate amount of energy for an uninterruptible supply to increase reliability requires storage like battery etc.

Efficiency of operation (E)

Increasing the production with a given amount of energy input by reduction in the wastage levels.

Environmental Impacts (EI)

During the process of energy conversion, heat is released in to the environment which involves various other pollutants in it that degrades and pollutes the environment.

Life-cycle of plants (LC)

It indicates the longevity of the plant.

Generation Cost (C)

It indicates the average cost of generating each useful unit of energy (e.g. kilowatt hour).

TABLE I. CAPITAL COST AND COST/MEGAWATT HOUR OF VARIOUS RENEWABLE RESOURCES

Sl. No.	**RENEWABLE RESOURCES (RR)**	**Capital cost(million USD/MW)**	**Cost/MWh (USD/MWh)**
1	PV	5.5-6	260-330
2	WG	0.87-1	50-76
3	BM	0.6-0.9	34-65
4	MH	0.9-1.1	20-43

III. Methodology using MCA in Renewable Resources Recognition

MCA is a decision support tool similar to AHP developed by Saaty wherein intangible factors are practiced based on subjective criteria to provide a numerical scale for measurement in prioritization of decision alternatives/options. The proposed MCA model based on AHP methodology is indicated below:

- The overall goal of the problem is to select the best RR.
- Factors or criteria for the decision, i.e. generation cost (GC), efficiency of operation (EO), environmental impacts (EI), life-cycle of plants (LC), reliability(R).
- The decision alternatives, i.e. PV, WG, BM and MH.

After identifying the criteria and the alternatives, they are placed into an AHP hierarchy as shown in Figure 2, which is then used to construct the normalized pairwise comparison matrix (PCM) as shown in Table II based on relative assigning value for four alternative (on nine-point scale as shown in Table II) on each criterion individually.

. TABLE II. NINE POINT SCALE OF PAIR-WISE COMPARISION

Intensity Measure (based on relative importance)	Scale Definition at 09 Point Measurement
1	Equally important
3	Moderately preferred
5	Equally preferred
7	Very strongly preferred
9	Extremely preferred
2,4,6,8	Intermediate judgment between two adjacent judgments

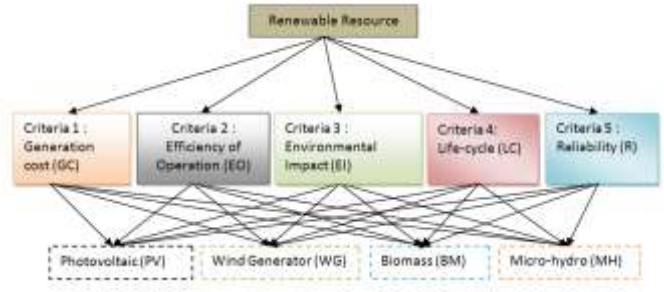

Figure 2.Hierarchy of RR selection pattern

IV. Results and Discussions

A variety of approaches have been planned to analyze renewable resources (RR). But so far no effort has been done on the fitting selection of RR which can extremely position wise (rural and urban etc.), organization wise (hospital, educational institute, industry areas, etc), customer wise (household, commercial, etc.) or demand wise, etc. The obtainable model has the inadequacy of meeting point only on a scrupulous place and/or cost factor. However, the current study stresses the expectation worries in the model. In a meticulous framework, to select the best choice of RR, precedence levels of different criteria can be in a specific form and further depends on priority vector as shown in Table III.

TABLE III. PCM (criterion X criterion)

RR	GC	EO	EI	LC	R	Priority Vector
GC	1	V_1	V_2	V_3	V_4	0.14
EO	V_5	1	V_6	V_7	V_8	0.18
EI	V_9	V_{10}	1	V_{11}	V_{12}	0.09
LC	V_{13}	V_{14}	V_{15}	1	V_{16}	0.17
R	V_{17}	V_{18}	V_{19}	V_{20}	1	0.11

Here, $V_{1.....}$ V_{20} are the values depending on the classification of variables used with respect to different criterion X criterion.

However, priority vectors show the different hypothetical values as a resultant of the criteria's in reference to PCM. These values may vary from the RR selection point of view having a relationship with major factors responsible in MCA model.

v. Conclusion

The renewable resources using MCA techniques is a powerful methodology and play a significant role in prioritization of different energy sources in the domain of renewable, which is a prominent case of the time. The alternatives especially from massive generation are possible from Renewable Energy Sources (RES) through new renewable energy technologies. We have seen that through factors selection of RR, it is quite easy and an effective measure to understand the best solutions for sustainable growth design in worst condition across the globe.

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