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Analyzing factors affecting biogas plant location considering Economic Environment and Social perspective

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ABSTRACT

The decision making process of selecting the optimal site for biogas plant out of possible alternatives can be said as a multi criteria problem whereas this issue could reach to an appropriate solution through a lot of knowledge about important location criteria. The best locations are favoured in terms of various characteristics including existing needs and defined objectives before final results. Bio energy has become the most optimistic resource of energy generation around the world in which biogas is one of the reliable products of renewable energy source, it is well known as eco-friendly bio fuel. The production of this gas is the most advantageous way of to minimize energy crisis. This research paper presents evaluation of the main criteria as well as sub criteria which are influential on the decision making process of choosing best site for biogas plants. The three necessary criteria i.e., Economic, Social and Environment were extracted from literature, expanding these each factor has been divided into sub factors. Data was collected through experts related to the field of biogas and other energy sectors. In order to rate the most influential factors five point Likert scale based questionnaire was sent to the local as well as international experts. Further Roger's adoption theory has been used and final factors were selected. The results shows total 17 sub factors collectively. These sub factors are separated for 3 main factors Economic posses six, Social has six and Environment has been finalized by 5 criteria for deciding the optimal location of biogas plant.

Keywords:

Biogas Plant
Green Energy
Location Criteria

1. Introduction

The maximum percentage of world's population depends on the usage of fossil fuels and this consumption is expected to be increased in future. The excessive use of fossil fuels has negative impacts on ecology, global climate and economy of the world. The replacement of fossil fuels has been carried out with raising awareness about renewable energy resources as these sources have positive role from different aspects. Biomass is one of the main renewable energy resources. Pakistan as an agrarian country has massive potential of biomass which is one of the main sources of gas energy and power generation in the country. Currently there are various sources of biomass production in Pakistan like Dung, solid waste, waste water coming out from

industries and houses etc. Burning of animal dung is like an in efficient path of utilizing biomass; conversion of biomass into biogas through anaerobic digestion can enhance the overall efficiency. The selection of an optimal site for biogas plant is a crucial task for decision making because this type decisions have a bounded relation with security of plants which should meet the environmental, social and economic requirements. It is not important that the sites having maximum available reservoirs if biomass are always feasible for biogas production plants. This decision making mission requires variety of criteria to be considered adding the above three main factors. Those criteria are needed to be considered addition with geographical information and other decisions making data in order to reach at a suitable solution.[1] Biogas categorized as one of the eco-friendly fuel having methane ratio of 60% and CO2 ratio as 40%. Production of biogas would be accomplished through biological process (anaerobic digestion) of organic matters of different wastes [2]. The technological advancements are needed for the operations of anaerobic plants, those production processes will provide appropriate data which will improve decision making models concerned with the location of biogas plants at regional and global stages. Biogas is rich in multiple benefits, it has been named as an Automotive fuel and also a source of energy for electricity generation [2]. To overcome energy problems the developing countries such as Pakistan considers biomass as a potential source of power generation and gas production within the country. As biogas has a property of high combustibility thus can be served as source of energy [3]. The usage of biogas shows positive impact over the environment through replacement of fossil fuels and minimizing emissions to the atmosphere[4].Biogas generating plants satisfy situations of producing energy and management of residues [5]. About 368,434,650 tons of animal dung is being generated annually in Pakistan. Karachi Landhi cattle colony possess 400,000 cattle waste that can be used for the production of biogas [6]. Previously, renewable energy technology in Pakistan was encouraged through establishment of (AEDB) Alternative Energy Development Board, targeted 5% generation of 9700 MW power via renewable energy by year 2030[6]. Decision for optimal location's choice depends on specified locations with respect to different criteria these locations are classified in scope, planning, patterns of firm and type of production. This research paper proposed the factors and sub factors which affect the location of biogas plant.

2. Research background

In the literature, different methods had proposed previously to defeat the problems related biogas facilities location. The most appropriate methods which are preferred to solve the

optimal location problem named as Geographic Information Systems and Multi Criteria Decision Making approaches. Since the value to choose an optimal location is finely recognized, various numbers of research and study has been conducted to identify the best places for biogas facility. The (GIS) has been projected to determine the possible location for biogas facility from cow waste for region of Lumphayakan Thailand [7]. The two multi criteria decision analysis methods one is the numerical taxonomy and other is Analytical Hierarchy Process were compared and being analyzed taking decision for best location of biogas plant location [8]. GIS based resource mapping and land suitability analysis was carried out by applying mixed integer programming. This study focused on establishment of centralized or community based anaerobic digester plants by using diary manure, case study united states [9]. Previously, a study was conducted in which 3 variations were assessed *via* AHP and TOPSIS multi criteria decision making methods for choosing locations of agriculture plant[10]. The Geographical Information System have been appeared as a potential mechanism to explore spatial information, it could operate and collect distinctive sets of data efficiently and easily be utilized for assessing energy resources [11]. Authors declared that the fuzzy logic, addition with weighted linear combination and Multi Criteria Decision Making was extremely correct for choosing effective places of solar plants. Fuzzy-AHP model was proposed to locate a solar based panel in Isfahan Province of IRAN [12].The study was carried out to recognize optimal location for bio-energy treatment plant, applied facility location model (e.g centre of gravity model and load distance model) and hot spot analysis in Arc GIS for Anambra State of Nigeria [13]. A study of GIS with multi-criteria decision making was proposed to select an operative location for the large wind turbine sin Thailand. The authors used AHP for analyzing relevant criteria[12].The Analytic hierarchy process is formulated via saaty's nine points scale, in which no.1 is equal significance, number 5 will show strong advantage, 3 would mention slight advantage, 7 as very strong advantage, and 9 means an absolute advantage [10]. A study was conducted by applying AHP technique, gave an extensive support system for decision making in order to level the criteria used for locating a sustainable desalination plant in country of UAE [14]. An optimal place for biomass power plant was investigated in the province of Granada (Spain),research was carried out through means of GIS and Multi-Criteria-Evaluation according to the AHP [15]. The study was conducted in southern Finland in which a local geographic information system procedure been established, for identification of possible sites, requirements of plants and the size of biogas facility on basis of transport distance and location of assets [16]. The table 01 shows the criteria proposed by different authors in articles.

Table 01: Factors and sub factors in reported in past literature

S.no	Factor	Sub factor	Definition	Ref.
1	Economic	Distance of major road	Total distance from Major road to biomass plant. It bounds material carrying cost.	[17]
		Distance of local road	Distance of alternative roads reaching at plant. Necessity of local road from waste generating point makes smooth transportation system.	[17]
		Existing land use.	Land use is a way of categorizing activities and types of activities explaining how existing land is used. i.e managing and modifying surroundings.	[17], [11], [14]
		Construction cost	The overall cost of whole construction project work such as cost of building, material and labour cost, transportation cost etc.	[14]
		Overhead cost	Cost needed for running a business. This will not be directly associated to a particular activity of business	[14]
		Water transfer costs	The cost linked with structure and facilities in transfer of water.	[14]
		Production potential	Generally it is capacity of an organization to produce a product.	[1]
		Low land	Specific region whose land is below sea level or at sea level. i.e: there would be no high mountains or hills.	[17]
		Investment cost	Cost required or given in the beginning of designing, installation and engineering of any industry or business.	[18]
		Production and operation cost	The sum of total costs required for producing a product. Whereas operation cost is related with operation of firm or operating system.	[18]
		Main road	The long important road connecting one city to another	[11]
		Potential demand	Total demand of product determining number of customers who use existing product or service	[19]
		Economic area	Region which is suitable to raise economy	[19]
		Transport cost	Cost paid by company or owner in order to transfer product from one location to another	[19]
2	Environment	Settlement distance	Distance from community of people.	[17]

		River distance	Distance from river to plant	[17]
		Land slope	Slope of land refers to the rise and fall occurs on surface of particular land.	[17], [11], [14], [20]
		Ecological sensitive areas	An area which is bioclimatic. i.e: designs of buildings in such area would be based upon local climate of that area.	[17], [18]
		Agricultural area distance	Distance from agriculture area.	[17], [19]
		Hydrology	Branch of science describes management of water as well as water's distribution and movement on earth	[19],[12]
		Temperature difference	Various temperatures of different areas	[14]
3	Social	Distribution system	It explains flow of practices and different activities. i.e: transport of goods and services to the customer.	[11]
		Company logo and image	Logo and image of a company is a representation of company by which customer recognize your product.	[14]
		Land ownership	It is real condition which shows rights and possession over land.	[14]
		Future urban growth	Increase in population and its impact on the social and economic life	[17]
		Population density	Area wise population thickness	[1]
		Work force	Presence of people for work	[18]
		Acceptance	It means to welcome something or real situation. Depends on person's choice.	[18]
		Quality of life	Perception of a person for his status contrast with norms and culture which he follows in life.	[18]
		Availability of biomass	Presence of agriculture, residential and other type of biomass.	[15]
		Residential buffer	Residential areas	[11]

The authors have worked for various factors affecting biogas plant locations. From literature 31 criteria were extracted under 3 main factors i.e: Economic, Social and Environment. The collected sub factors are considered as very large data. In order to minimize the sub factors were reduced to a limited number and important sub criteria were taken for the site selection of biogas plant.

3. Research methodology

In this research from the literature it has been observed that there are various studies conducted in the field of biomass and the biogas plant location problems. As it is Multi criteria decision

making issue the researchers investigated number of various criteria which are related to areas of decision making as mentioned in table 01**.** The criteria selection depends upon the own choice of researches and experts concerned with biogas and energy sectors as many of the authors have merged factors into one another according to previous studies and experts opinion. However it was very much tricky to analyze all the factors for each location as in this research overall 31 sub factors of three main criteria were carried out. To overcome this issue a questionnaire was designed and sent through online channels like: Linked In, Whatsapp and gmail. It was sent to experts who are linked with the field of biogas working at local and international levels. The questions were designed in such a way that each sub factor has been placed as a question so that experts can easily rate each factor. For the rate of each criterion 5 point Likert scale was used as shown in table 02.

Table 02: 5 point Likert scale

Point	Not Important	Less Important	Moderately Important	Important	Very Important
Scale	1	2	3	4	5

After collecting the questionnaire data the Rogers adoption theory has been applied for selection of important sub factors. Rogers (2003) had explained the adoption rate as "The speed with which an individual accept the new change that is occurred in social system." Rogers categorized the individuals in a social system i.e: organization on basis of adoption rate. He classified the members who are relatively fast to accept the new changes than the persons who are less interested in adoption of new ideas. Thus Rogers' Illustration of adopters is mentioned in Fig. 01.

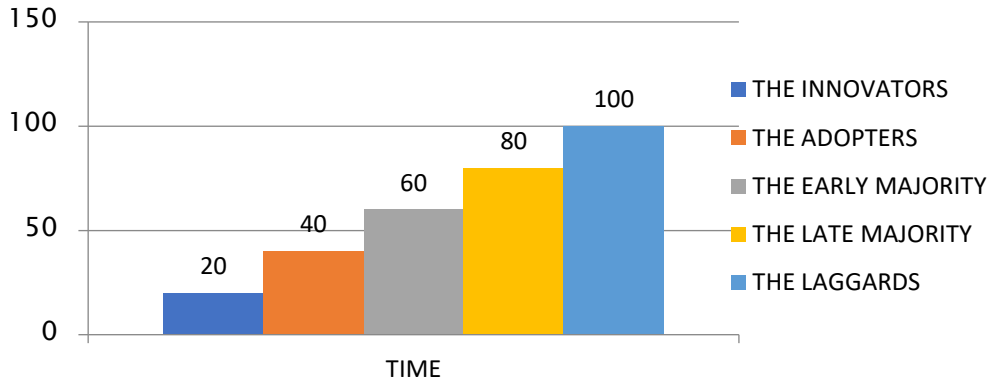

Fig. 01: Rogers' Illustration

Furthermore Altson, Miller (2002) and Mohammad (2014) researched and used Rogers' innovation diffusion theory with an interpretation of the same Likert scale as given in table 03,

Table 03: Likert scale

Likert scale	Range Value Allocation	Innovation Rogers Adoption Status
Not Effective	0.1 to 1.0	Laggard
Less Effective	1.1 to 2.0	Late, Majority
Moderately Effective	2.1 to 3.0	Early, Majority
Effective	3.1 to 4.0	Adopters
Highly Effective	4.1 to 5.0	Innovators

Thus, the collection of questionnaire shows the rated factors by the experts. The mean average of all the responses has been taken out through MS Excel, after getting an outcome for each criteria the ratings were carried out by range allocation keeping in view the Rogers's interoperated scale, only the Effective that ranges from 3.0-4.0 and Highly Effective 4.1-5.0 has been chosen for the reduction of sub factors. Though there were some sub factors which were interrelated to one another. The literature articles were reviewed again and sub criteria are renamed also merged with the other. The experts' opinions are also considered in group discussions after getting the outcome for factors in order to finalize the most important factors.

4. Results

The results show selected ranges for factors. Based on the experts' opinion the following sub factors has been placed in the area of suitable criteria and total 17 sub factors were finalized including 3 criteria *i.e.,* Economic possess six, social also includes 6 and environment has been separated with 5 sub criteria as shown in table 04.

Table 04: Finalized factors and sub factors

Economic	Distance of major road
	Construction cost and investment cost
	Production and operation cost
	Potential demand
	Transport cost
	Economic area
Social	Population density
	Work force
	Distribution system
	Social Acceptance
	Quality of life
	Future urban growth
Environment	Ecological sensitive areas
	Hydrology
	Land slope
	Settlement distance
	Existing land use

5. Conclusion

Biogas is one of the most important energy sources that is increasingly contributing to world for energy outcomes. Selection of biogas plant location is most complex issue in renewable energy projects for this a decision-maker must consider the quantitative and qualitative factors in order to choose the right location by implementation of the considered key success factors. The study shows 3 main factors including 17 sub factors which are necessary to analyze before choosing an optimal location of biogas plant. The findings of the present study are expected to be helpful for the researchers as well as energy stakeholders working in any region, so that they can consider these factors first then make a good decision and finally they can select the best site for biogas plant.

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