JREE: Vol. 2, No. 1, (Winter 2015) 1-5

Journal of Renewable Energy and Environment

Research Article

Journal Homepage: www.jree.ir

Making Decision Support System for Utilization of Biogas in Iran

M. Nosratinia*[a], A.A. Tofigh[b] , M. Adl[c]

[a]Department o Industrial Engineering, Materials and Energy Research Center ,Karaj, Iran
[b]Department of Industrial Engineering, AmirKabir University of Technology, Tehran, Iran
[c]Department of Energy, Materials and Energy Research Center, Karaj, Iran

P A P E R I N F O

Paper history:
Received 26 October 2013
Accepted in revised form 14 October 2014

Keywords:
Biogas
Decision Support System
Analytical hierarchy process (AHP)
multi-criteria decision making (MCDA)

A B S T R A C T

The use of renewable energy sources is often suggested to be a good solution for climate change and the dependency to fossil fuel. Biogas utilization is a one of these promising options that can mitigate these problems since biogas is produced by the fermentation of waste, so is rich in methane and has the same characteristics as natural gas. Biogas has increasingly been noticed in different countries during last decades, but Iran could not reach its deserved position in comparison with others. The authors believe that absence of a proper management and information system is the main reason for this problem. In this article a decision system is designed in order to reduce the involved risks in making decision and helping in selecting the most appropriate commercialization strategies for utilization of biogas which is achievable from Iran's livestock and poultry wastes. After a short hint to biogas and its techniques, in this article the main related criteria including biogas site selection and production techniques and utilization options in Iran have been chosen and their weights were calculated according to analytical hierarchy process (AHP). The weight obtained in this research should be considered in future development of Biogas by considering local specifications.

1. INTRODUCTION

Livestock dung and poultry manure are usually released unused in the nature or used in farms as fertilizer, and in some cases they are burned in order to generate heat. Released wastes in the nature cause environmental problems such as odor, water pollution and so on. One of the acceptable solutions with considerable economic and environmental benefits is anaerobic digestion of organic materials. Biogas and digestate with better quality are the main products of digestion process.

Biogas production occurs naturally in flooded land, rice cultivations and in ruminants' stomach [1]. Biogas can be used as fuel in place of fossil fuel and would be useful in mitigation of global warming and CO_2 emissions. Different sorts of organic materials such as plants, livestock manure, waste from provisions, sewerage sludge or household waste are used in human controlled biogas production [2].

By increasing in size and complexity of biogas systems, managing the information becomes more difficult; therefore, existence of a precise support system is necessary for development of biogas facilities.

*Corresponding Author's Email : m_nosratinia@yahoo.com(M.Nosratinia)

There are two main problems related to this issue, first: data acquisition from production and utilization of biogas, and second, connecting this information to each other and extending them for better understanding of different kinds of biogas systems. The solution for the first one is gathering adjective information that define this system such as protocols, guidelines, handbooks and so on, for the second one, we need to investigate the relation between information categories by using techniques that cover different needs in different situations. Our focus is on resolving the second problem, and we have designed a decision support system that connects information related to construction of an anaerobic digester facility together, and the user will use this information better in their future decision.

In this paper, we do not intend to make a decision, but want to show the direction and give insight to investors, how they encounter with this project and which factors they should consider.

2. BIOGAS STATUS IN IRAN

Although Iran is a member of OPEC and has abundant reserves of fossil energies, it must pay attention to renewable energies owning to its rapidly increased energy demand. Furthermore, Iran has joined Kyoto protocol, which obligates the members to reduce their carbon emissions [3]. On the other hand, using fossil fuel cause environmental pollution and global warming. Recently, Iran has omitted subsides in energy, this corresponds to increase in fuel fees and rising importance of renewable energies in this country.

In Iran, 8600 million m3 of biogas can be produced from livestock excreta annually [20]. In spite of this high potential and many researches that have been performed in the field of biogas in Iran (around 510 articles so far in different aspects of biogas in different Journals), the result is disappointing.

As mentioned in the report by Adl [3], among 71 projects in Iran from 1980s till 2008, less than five units have been active and only 18 out of 40 constructed units by RCD reached gas generation stage at the time of operation [3]. These records show that the real problem in this field is not lack of knowledge, but improper information management system.

Biogas facilities in Iran have been built by several organizations, and unlike developed countries, there is no need for permits regarding health and environmental problems for the construction of biogas plants, and there are not organizations in charge of monitoring and collecting data centers. As a result, there is no possibility of knowledge transfer between these centers, each center is acting independently and prepares a limited number of papers only as the output.

3. DECISION SUPPORT SYSTEM

Although research has been done in making decision support system in biogas, but they have considered all factors. For example, Cristian Cardenas et al. [5], that only have presented a decision support application for calculating the amount of biogas by using Microsoft visual Basic [5]. Ioannis et al. have outlined a decision support system (DSS) methodology based on Multi-Criteria Decision Analysis (MCDA) to compare six alternative investment options for small-scale biogas applications in /European islands and in particular a system that applies the multi criteria outranking technique PROMETHEE (preference ranking method for environment evaluation) [6].

Absence of such analysis in renewable energy especially in biogas is evident and this article is answering this urgent need. In this article, first, we describe MCDM and AHP weighting method. Next section is about exploration of factors related to selecting the appropriate region for biogas production plant and weighting them. In Section 5, the most popular methods in biogas production and consumption is introduced, and then, the weight of each one calculated by using AHP. These weights can be used for selecting among different biogas techniques in order to reach the appropriate one for each location.

4. USING MCDM IN RENEWABLE ENERGY

Multiple-criteria decision-making or multiple-criteria decision analysis (MCDA) is a sub-discipline of operations research that explicitly considers multiple criteria in decision-making environments. Each alternative can be evaluated in terms of the decision criteria, and the relative importance (or weight) of each criterion can be estimated as well. Some researchers have used MCDM in renewable energies; Heracles Polatidis, et al .[7], presented a MCDM analysis methodology for renewable energy applications, and Stephan Bojnec, et al. [8], have worked on development of biogas energy production and used it in Slovenia Also, Macharis et al. [9] and Behzadian et al. [10] have successfully applied MCDA in many fields of renewable energy and waste management. These techniques include several methods and we will use the analytic hierarchy process (AHP) in our article.

4.1. Analytic hierarchy process (AHP) Each criterion has a different influence on evaluation result. The well-known approach for generating subjective weights is analytic hierarchy process (AHP) which involves decomposing a complex decision into a hierarchy with goal at the top of the hierarchy, criteria and sub-criteria at the first and second level, and decision alternatives at the bottom of the hierarchy (11-13). In the AHP, the calculation method proposed by Saaty [14] was based on crisp judgment. AHP is popularly used in renewable energy planning [15-17]and can be expressed as following steps:

- Establishment of the index system and hierarchy model construction.
- Factors and sub-factors weight calculation.
- The regional suitability degree value

The local weights of the factors and sub-factors are calculated using pairwise comparison matrices. Pairwise comparison judgments are made using Likert scales regarding relative importance.

5. LOCATING OF BIOGAS FACILITIES

Purpose of this part is predicting the locations that have high biogas potential and have ready access to road and electricity. In this procedure, existing limitations like environmental and legal restrictions should be considered. The information about population, seasonal immigration rate and energy use per capita are also needed. For analyzing data, GIS tool can be used. GIS is a powerful tool for geographical survey; but, for using this tool, first we need to know the criteria and their weights. The purpose of this article is getting these weights.

5.1. Criteria and weight for site location The methodology for this part is determination of important factors that affects site location.

TABLE 1. Characteristics of input ground motion

Main criteria	Local weight	Sub-criteria		Sub-criteria weight	Global weight
Construction	0.40	Road	Paved way	0.1	0.04
			Highway	0.4	0.16
			Malraux way	0.05	0.02
		Electricity Grid		0.25	0.1
		CNG stations		0.2	0.08
Population group	0.35	Urban		0.76	0.266
		Rural		0.24	0.084
Feature	0.12	Slope		0.48	0.0576
		Height		0.52	0.0624
Geographic limitation	0.13	Flood		0.22	0.0286
		Earthquake Fault		0.21	0.0273
		Protected area		0.19	0.0247
		Forest		0.18	0.0234
		Mine		0.20	0.026

After consulting the experts in biogas field on factors related to site location for installing a biogas plant, we have chosen 4 main criteria, namely: construction, population, feature and geographic limitation, and 12 sub criteria for site location. Table 1 shows these criteria and their calculated weights using AHP method for Iran. It shows that being near urban, highway and Electricity grid is the main factor that can affect success in biogas plants.

6. BIOGAS TECHNOLOGY

We divided the technology related to biogas in to 2 main groups, Biogas producing methods and Biogas usage, each one includes different methods and have negative and positive affection.

6.1. Biogas producing methods There are different types of Biogas digesters that include prefabricated biogas digesters (PBD) which are prototypes derived from traditional Domestic biogas digesters (DBDs). Developing countries use three major types of DBDs, namely: the fixed dome digester, the floating drum digester (also called the telescoping digester), and the plug flow digester (also called the sausage-bag or channel digester) [21, 22]. PBDs can be processed and produced with different materials based on different DBD models. Existing PBDs do not have an exact classification. PBDs are typically called "commercialized digesters." These digesters are also called "three new digesters" because they typically adopt: (i) new production materials, (ii) processes, and (iii) techniques. According to the China Association of Rural Energy Industry (CAREI), PBDs or commercial digesters are classified as fiber- reinforced plastic (FRP), plastic soft (PS), and plastic hard (PH); each of these categories have their benefits and disadvantages, and each one works better in certain conditions and is affected by several factors such as local temperature, and so on [23].

6.2. Biogas usage We can use biogas in various methods such as generating power and heat from biogas or purify and use it as vehicle fuel, or inject it into the gas grid. Figure 1. shows a Biogas utilization facility.

As one of the renewable energy conversion technologies, biogas fired CCHP system has been focused on more and more areas of concern. Because of its lower pollutant emissions in comparison to fossil fuel and clean energy, if this kind of renewable energy can be utilized, the energy-related problems such as increasing energy demands and energy depletion of non- renewable energy resources can be solved as well as environ- mental issues such as global warming and acidification effects [18].

If the biogas is burnt in an on-site engine or CHP, only a primary cleaning is needed (dehumidification and desulfurization) to remove the corrosive matters that damage the engines.

Also, the additional processing and feeding of the biomethane into the natural gas grid allows a decentralized valorization of the energy: the biomethane can be drawn from and used, anywhere, in the natural gas grid the regulatory framework of the country usually states which kind of biomethane can be injected, and under which conditions. Then, the grid operators publish their technical specifications on biomethane quality.

Another option for biogas usage is as vehicle fuel. The transport sector is the first oil consumer at the world scale (51% of the final oil consumption) far ahead from the industry (34% of the final oil consumption) and residential (6% of the final oil consumption) sectors [19].

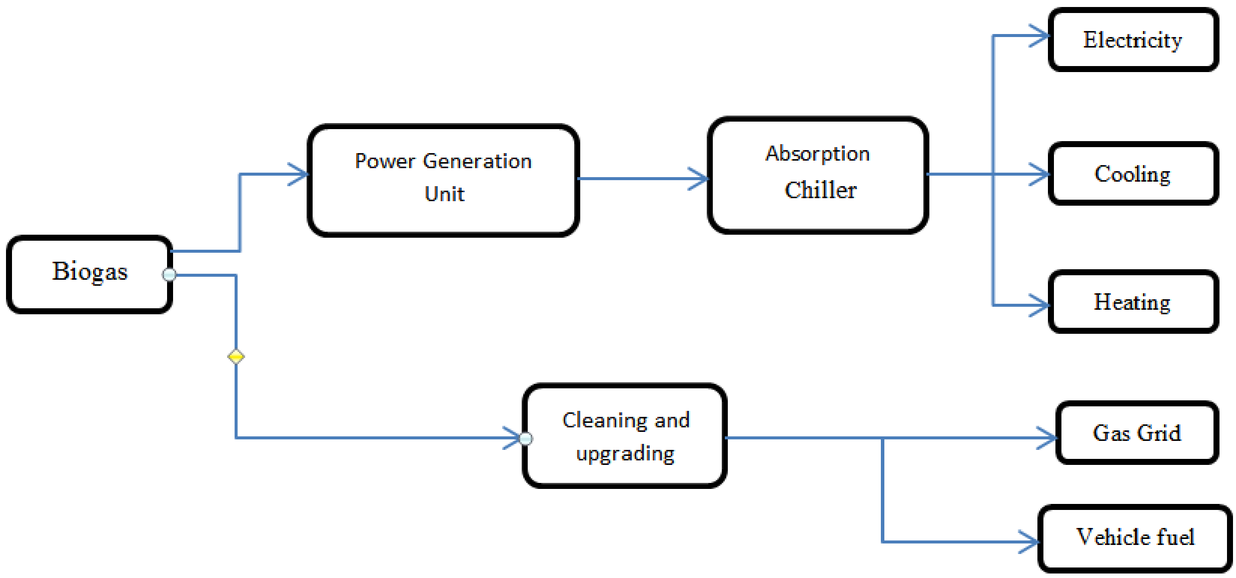

Figure 1: Biogas use

The energy consumption for transportation uses has nearly doubled between 1973 and 2006 (96%), with a 20% growth since 1990 [15]. According to the International Energy Agency (2010), the energy consumption in the transport sector could increase by 30% between 2010 and 2030.
CNG (Compressed Natural Gas) is an alternative fuel to the "conventional" transport fuels (diesel oil and gasoline), allowing a decreasing of the dependency on petroleum and a diversification of the sources of fuel supply, that is important not only from an economic point of view, but also in order to secure the energy supply. Utilizing biogas as a transportation fuel, raw biogas has to undergo two major processes: cleaning and upgrading, to achieve natural gas quality. The upgraded biogas (so called bio-methane or bio-CNG) is considered green fuel with respect to environment, climate, and human health. However, the resulting bio-CNG from the processes still needs to be evaluated in terms of greenhouse gas emissions and energy aspects.

6.3. Criteria and weights for technology selecting Table 3 summarizes criteria for making decision in biogas field based on expert's viewpoints and Ioannis et al. [6] research. We divided these criteria into 4 major groups: economic, eco-environmental, social and technical factors and 12 sub-criteria. External Non-Technical Barriers is related to regulation and standards, legislated in each country. Energy coverage shows if this new energy would be able to replace fossil fuel. There is two types of criteria, positive and negative. If positive ones be higher, it would be better and have plus effect, and vice versa.
For weighting criteria we have designed questioners and used AHP (Analytic Hierarchy Process) method to calculate its weighs. We should consider this point that weights should be adjusted for different situations and according to decision maker's requirements.
The results show (Table 2) that the most important factor is NPV (net present value) with a value of 0.2 followed by GHG emission reduction which is 0.14. The next factors are fossil fuel saving coverage, 0.13, and internal rate of return (IRR), 0.11.Less important factor in related to Biogas installation is odour reduction.

7. CONCLUSIONS

Biogas as a renewable energy source has a great potential in Iran, nevertheless it has not reached its deserved position so far.
As mentioned in part 2, the Authors believe that the main problem in biogas field in Iran is not lack of knowledge, but improper information management system.
In this article, the main criteria and their importance are analyzed using experts view. Although making such DSS is time-consuming and complex, but it would be a basic help for governments and investors in biogas field, so that they can choose projects that have higher commercialization potential and can select the best ways of biogas production and usage.
Information management system can also decrease the risk involved in projects. Making such support system

TABLE 2. Decision Criteria

Criteria	*sub Criteria*	*Criteria Property*	*Criteria direction*	*weight*
Economic	Net profit value (NPV)	Quantative	Max	٠,٢٠
	Internal rate of return IRR(%)	Quantative	Max	٠,١١
	Payback Period(yrs)	Quantative	Min	٠,١
	Investment Capital Cost	Quantative	Min	٠,١٠
	GHG emission on reduction(ton/m3/y)	Quantative	Max	٠,١٤
Eco-enviromental	Fossil fuel savings (t0 e)	Quantative	Max	٠,١٣
	Replaced tons of chemical fertilizers(tons)	Quantative	Max	٠,٦

for other kinds of renewable energy in Iran is suggested for future researches.

8. ACKNOWLEDGE

The authors would like to acknowledge the Materials and Energy Research Center, for their support and contribution to this study and We also thank Dr Pazouki (Editor in chief of JREE , Materials and Energy Research Center, Karaj, Iran) for providing us technical supports**.**

REFERENCES

1. Norin, E., "BIOGAS –Eller vad man kan gora av ruttna applen", Swedish Biogas Association, Stockholm, (1998).
2. Person, M., "Evaluation of upgrading techniques for biogas", Lund Institute of Technology, (2003).
3. Adl, M. and Omrani, G. A., "Background of biogas technology and its recent developments in Iran", ***International Journal of Global Energy Issues***, Vol. 29, (2008), 3.
4. I.R. Iran Ministry of Agriculture, Agricultural Statistics Report, (2011).
5. Cristian, C. L. and Lahoti, A., "A biogas decision support system tool", Latin American and Caribbean Conference for Engineering and Technology "Innovation and Development for the Americas", (2010).
6. Venetis, I.A., "Reinforcing investments in biogas technologies for small-scale RES applications in islands", Partner Responsible: University of Patras, (2009).
7. Polatidis, H., Haralambopoulos, D.A., Bruinsma, F., Vreeker, R. and Munda, G., "Decision Aid with the MCDA-RES software: A Wind-Hydro Energy Application for an Island of the Aegean, Greece", ***Energy Sources***, ***Part B: Economics, Planning,*** Vol 4, (2009), 407–419.
8. Bojnec, S. and Papler, D., "Biogas energy development in slovenia", ***International Journal of Engineering***, (2013), 77-86
9. Macharis, C., Springael, J., Brucker, K.D. and Verbeke, A., "PROMETHEE and AHP: The design of operational synergies in multi criteria analysis. Strengthening PROMETHEE with ideas of AHP", ***European Journal of Operational Research***, (2004), 153: 307 – 317.
10. Behzadian, M., Kazemzadeh, R.B., Albadvi, A. and Aghdasi, M., "PROMETHEE: A comprehensive literature review on methodologies and applications", ***European Journal of Operational Research***, Vol 22, (2010), 198-215.
11. Szczypinska, A. and Piotrowski, E.W., "Projective market model approach to AHP decision making", ***Physical a-Statistical Mechanics and Its Applications***, Vol 15, (2008), 3982–3986.
12. Yang, J. and Lee, H., "An AHP decision model for facility location selection", ***Facilities***, Vol 15, (1997), 241–254.
13. Tzeng, G.H., Teng, M.H., Chen, J.J. and Opricovic S., "Multi criteria selection for a restaurant location in Taipei", ***International Journal of Hospitality Management***, Vol 21, (2002), 171–187.
14. Saaty, T.L., "The analytic hierarchy process: planning, priority setting, resource allocation", ***New York/London: McGraw-Hill International Book Co***, (1980).
15. Rahman, S. and Frair, L.C., "A hierarchical approach to electric utility planning", ***International Journal of Energy Research***, Vol 8, (1984),185–196.
16. Zong, W. and Zhihong, W., "Mitigation assessment results and priorities for China's energy sector", ***Applied Energy***, Vol 56, (1997), 237–251.
17. Akash, B.A., Mamlook, R. and Mohsen, M.S., "Multi-criteria selection of electric power plants using analytical hierarchy process" ***Electric Power Systems Research***, Vol 52, (1999), 29–35.
18. Ou, X., Zhang, X., Chang, S. and Guo, Q., "Energy consumption and GHG emissions of six biofuel pathways by LCA in (the) People's Republic of China", ***Applied Energy***, Vol 86, (2009), 5197–5208.
19. Energy Technology Perspectives. International Energy Agency**,** (2010).
20. Afazeli, H., Jafari, A., Rafiee, SH. and Nosrati, M., "An investigation of biogas production potential from livestock and slaughterhouse wastes", ***Renewable and Sustainable Energy Reviews***, Vol 34, (2014), 380–386.
21. Plöch, M. and Heiermann, M., "Biogas farming in central and northern Europe: a strategy for developing countries? ***Agricultural Engineering International: the CIGRE journal***, Vol 8, (2006), 1–15.
22. Rajendran, K., Aslanzadeh, S. and Taherzadeh, M.J., "House holding as digesters-a review", ***Energies,*** Vol 5, (2012), 2911–2942.
23. Cheng, S., Zifu, L., Mang, H.P., Huba, E.M., Gao, R. and Wang, X., "Development and application of prefabricated biogas digesters in developing countrie", ***Renewable and Sustainable Energy Reviews,*** Vol 34, (2014), 387–400.