# RANKING OF MULTIFACETED CRITERIA FOR THE VARIOUS $H_2S$ REMOVAL TECHNOLOGIES FROM BIOGAS USING ANALYTIC HIERARCHY PROCESS

**Sudeep Yadav[1], Amitabh K. Srivastava[2], R.S.Singh[3]**

*[1]Assistant Professor, Department of Chemical Engineering,*
*Bundelkhand Institute of Engineering and Technology, Jhansi, (India)*
*[2]Associate Professor, Department of Civil Engineering,*
*Bundelkhand Institute of Engineering and Technology, Jhansi, (India)*
*[3]Associate Professor, Department of Chemical Engineering,*
*Indian Institute of Technology-BHU, Varanasi, (India)*

**ABSTRACT**

*Biogas, a clean and renewable form of energy could very well substitute for nonrenewal sources of energy. Biogas is a mixture of mainly methane ($CH_4$) and carbon dioxide ($CO_2$) with small amounts of sulfuric component ($H_2S$). The chemical energy contained in biogas is converted into heat or electricity through combustion. In both cases biogas quality is the key factor in terms of methane content and purity. The Hydrogen sulfide is typically the most problematic contaminant because it is toxic and corrosive to most equipment. Removing $H_2S$ as soon as possible is recommended to protect downstream equipment, increase safety, and enable possible utilization of more efficient technologies. Packed Tower Absorption (Water Scrubbing),Chemical Reaction with Iron oxide (& its Derivatives),Chemical reaction with Zinc Oxide, Chemical Reaction with Lime ,Iron Chelation Method, Adsorption on Carbon Molecular Sieves are the main available Technologies for the removal of $H_2S$ from Biogas.*

*Each type of Technologies has its merits and demerits. In order to selecting the most appropriate Technology among them are very important to gain the optimal benefit. To deal with such complex decision making problems, The Analytic Hierarchy Process (AHP) a Multi criteria Decision Model introduced by Thomas Saaty, is an effective tool. In this research, ranking of multifaceted criteria like Technology Maturity, Technology Availability, Initial Investment Cost, Operation Cost, Process Efficiency and Process Emissions is done by using AHP (Super Decision Software) for the prioritization of $H_2S$ Removal Technology from Biogas.*

***Key Words:, Biogas, $H_2S$ Removal Technologies, Analytical Hierarchical Process, Multifaceted criteria, Super Decision Software***

## I. INTRODUCTION

Energy is vital for development and this means that if India is to move to a higher growth route than is now feasible, it must ensure the reliable availability of energy. The present energy scenario in India is not reasonable. The Energy supply position existing in the country is characterized by persistent shortages and unreliability and also high prices for industrial consumers. There is also anxiety about the position regarding fossil fuels. India depends to the extent of about seventy percent on imported fuel, and this obviously raises question about energy security. These concerns have been worse by recent movements in international oil prices. Electricity is produced domestically but its supply depends upon the availability of coal, use of hydro power sources and the scope for expanding nuclear power, and there are restraint affecting each source. Vibrant functioning society needs energy as its lifeline and the quantum of its use indicates the quality of life being experienced by its members. There is a great disparity in the energy use amongst different regions of the world and even for countries like India where the rural areas are bereft of the benefits of energy and where obtaining food and shelter is a daily challenge. India needs to bridge this divide as soon as possible and this is of paramount importance for any growth which should include all sections of society [1].

India needs to realize the vast potential of renewable energy and need to step up effort for attaining the goal by 2020 i.e. 20% reduction in GHG, 11% reduction in consumption of energy by bringing about attitudinal changes, 20% share of renewable energy and 20% conservation of energy from the year 2011 till 2020. These targets are attainable and not only provide cleaner energy but also open a new field for providing employment opportunities to millions of people who are unemployed. This thrust then needs to be maintained so that India attains a target of having 70% renewable energy uses by 2050 [2].

There are many types of renewable resources like- wind energy, solar energy, geothermal energy, fuel cell, ocean energy, and biomass. Although these are pollution free but have some limitation like limited sites in India and also lack of appropriate technology for extraction of energy from these sources. India is second largest country of the world and the economy is based on agriculture. In India agriculture profession creates lots of residue and animal excreta are also available in adequate quantity. If these are not handled properly, this may create environmental pollution and also human health. Hence from above explanation this clear that India has large scope of biomass. In India energy crises and environmental problem can be solved by the help of biomass.

Biogas is produced by the anaerobic digestion or fermentation of biodegradable materials. Biogas is a renewable energy source and can replace fossil fuel. Anaerobic digestion is often the only possibility of producing biogas from manure. By definition, anaerobic digestion is a microbiological process during which organic matter is decomposed into biogas and microbial biomass in the absence of air. There has been growing interest in biogas which is bio-energy source resulting from the conversion of natural biomass. Biogas consists mainly of methane ($CH_4$) and carbon dioxide ($CO_2$), with smaller amounts of water vapor and trace amounts of hydrogen sulfide ($H_2S$), and other impurities. Various degrees of gas processing are necessary depending on the desired gas consumption process. Hydrogen sulfide is typically the most challenging contaminant because it is toxic and corrosive to most equipment. Additionally, combustion of $H_2S$ leads to sulfur dioxide emissions, which have harmful environmental effects. Removing $H_2S$ as soon as possible is recommended to protect downstream equipment, increase safety, and enable possible utilization of more efficient technologies such as micro turbines and fuel cells [3].

Most biogas purification methods are derived from conventional gas separation technologies and many of them have been successfully applied for natural gas purification. Commonly used technologies are Packed Tower Absorption (Water Scrubbing), Chemical Reaction with Iron oxide (& its Derivatives), Chemical reaction with Zinc Oxide, Chemical Reaction with Lime, Iron Chelation Method, Adsorption on Carbon Molecular Sieves.

Each type of $H_2S$ removal from Biogas technology has its merits and demerits, so that selecting the most appropriate removal Technology among them is very important to gain the best possible option. The Analytic

Hierarchy Process (AHP) a MCDM model introduced by Thomas Saaty, is a useful tool for dealing with such complex decision making.

The principles and philosophy of the theory of this multi criteria decision making technique were explained giving background information of the type of measurement utilized, its properties and applications (Saaty 1990). It is becoming quite popular in research due to the fact that its utility outweighs other rating methods (Eddi and Hang 2001). The AHP methodology has been accepted by the international scientific community as a robust and flexible multi-criteria decision-making tool for dealing with complex decision problems (Elkarmi and Mustafa 1993). The potency of the AHP approach is based on breaking the complex decision problem in a logical manner into many small but related sub-problems in the form of levels of a hierarchy. The hierarchical structure of the AHP model permits decision- makers to compare the different prioritization criteria and alternatives more effectively. The AHP may involve group discussion and dynamic adjustments to finally arrive to a consensus [4, 5].

In the present study, an attempt has been made to arrive at the ranking of multifaceted criteria like Technology Maturity (Technical Aspects Only), Technology Availability (In India), Initial Investment Cost, Operation Cost, Process Efficiency and Process Emissions (Air, Water & Ground) using AHP (Super Decision Software) for the prioritization of most appropriate Removal Technology of $H_2S$ removal from Biogas in Indian context.

## II. VARIOUS REMOVAL TECHNOLOGIES OF $H_2S$ FROM BIOGAS

Removal of $H_2S$ from Biogas can be accomplished by using a number of different Technologies like Packed Tower Absorption (Water Scrubbing), Chemical Reaction with Iron oxide (& its Derivatives), Chemical reaction with Zinc Oxide, Chemical Reaction with Lime ,Iron Chelation Method, Adsorption on Carbon Molecular Sieves. Factors that influence the choice of removal process are: the type and quantity of biogas available, the ultimate application of energy, environmental norms and economic viability. The Brief discussion of $H_2S$ removal Technologies from Biogas is given below:

### 2.1 Packed Tower Absorption (Water Scrubbing)

Pressurized water scrubbing (PWS) is the most commonly used method for the purification of biogas. It is fundamentally based on the principle that the solubility of $CO_2$ and $H_2S$ is higher in water as compared to $CH_4$, thus separating both $CO_2$ and $H_2S$ simultaneously from biogas with a high efficiency is easy. To increase the absorption of $CO_2$ and $H_2S$, Biogas is usually compressed to about 1000 kPa and a packing media which has a high surface area is used. Inside the scrubber, the flow of biogas keeps counter currently with respect to water flow that is sprayed from the top of scrubber, and the absorption primarily occurs on the surface of the packing media. Cleaned biogas can contain more than 96% $CH_4$ after drying. The liquid effluent contains a high concentration of $CO_2$ and a low concentration of methane. It is recycled in the flash tank where pressure is lowered to 200–400 kPa. Finally, water is regenerated in the stripper at near atmospheric pressure with air blown into the stripper. The advantages of this method include no need for chemicals and simultaneous removal of $CO_2$, $H_2S$, and other impurities which are soluble in water, e.g. Dust and Ammonia ($NH_3$).The main challenge of this method is that its demand of water is very high [6-7]. $H_2S$ has a slightly higher solubility than $CO_2$, but costs associated with selective removal of $H_2S$ using water scrubbing have not yet shown competitive with other methods. Therefore, water scrubbing will probably only be considered for the simultaneous removal of both $H_2S$ and $CO_2$.

### 2.2 Chemical Reaction with Iron oxide (& its Derivatives)

Iron-oxide impregnated wood-chips selectively adsorb $H_2S$ and mercaptans. The primary active ingredients are hydrated iron oxides ($Fe_2O_3$) of alpha and gamma crystalline structures. The mixed oxide, $Fe_3O_4$ ($Fe_2O_3.FeO$), also contributes to the activity present. The chemical reactions involved are shown in the following equations

$Fe_2O_3 + 3H_2S \rightarrow Fe_2S_3 + 3H_2O$

$Fe_2S_3 + 3/2O_2 \rightarrow Fe_2O_3 + 3S$ ($\Delta H = -198$ MJ/kmol $H_2S$)

Like all gas-solid adsorption processes, iron-sponge-based $H_2S$ removal is operated in batch mode with separate regeneration, or with a small flow of air in the gas stream for continuous, at least partial, regeneration. The iron sponge can be operated in batch mode with separate regeneration, or with a small flow of air in the gas stream for continuous revification. It is imperative to manage heat build-up in the sponge during regeneration to maintain activity and prevent combustion. Due to $S^0$ build-up and loss of hydration water, iron-sponge activity is reduced by about one third after each regeneration cycle. Therefore, regeneration is only practical once or twice before a new iron sponge is needed.While the benefits of the iron sponge also comprise simple and effective operation, there are critical drawbacks to this technology that have led to its decreased usage in recent years. The process is highly chemical-intensive; operating costs can be high; and a continuous stream of spent waste material is accumulated. Additionally, the change-out process is labor-intensive, and can be troublesome if heat is not dissipated during regeneration. Perhaps most importantly, the safe disposal of spent iron sponges has become problematic, and in some instances, spent media may be considered as hazardous waste requiring special disposal procedures. Land filling on site is still practiced, but has become riskier due to fear of the need for future remediation [8-9].

### 2.3 Chemical Reaction with Zinc Oxide

Zinc oxides are preferred for removal of trace amounts of hydrogen sulfide from gases at elevated temperatures due to their increased selectivity over iron oxide. Typically in the form of cylindrical extrudates 3-4 mm in diameter and 8-10 mm in length, zinc oxides are used in dry-box or fluidized-bed configurations. Hydrogen sulfide reacts with zinc oxide to form an insoluble zinc sulfide via Equation:

$$ZnO + H_2S = ZnS + H_2O$$

Zinc-oxide processes are available in several forms for operation at temperatures from about 200° C to 400° C. Maximum sulfur loading is typically in the range of 30-40 kg sulfur/100 kg sorbent for these processes. Formation of zinc sulfide is irreversible and zinc oxide is not very reactive with 24 organic sulfur compounds. If removal of mercaptans is also desired, catalytic hydro desulfurization to convert these compounds to the more reactive hydrogen sulfide is needed first [10].

### 2.4 Chemical Reaction with Lime

Maizirwan Mel et. al (2014) used Aqueous solution of Ca $(OH)_2$ as chemical solvent to demonstrate its ability and effectiveness in absorbing $CO_2$ and $H_2S$ from biogas. Different operating parameters which include concentration of limewater solution and flow rate of biogas were used. Methane ($CH_4$) composition after treatment was also studied as removal of impurities is interrelated to $CH_4$ enhancement. The concentrations of limewater were varied, as well as the biogas flow rates. Experiments done reveal the highest $CO_2$ removal efficiency can be achieved with 14% concentration of limewater solution and the highest absorption capacity was achieved with 1.0 l/min of biogas flow rate. Increment is about 21.2% from its original value. These results indicate that the highest performance of limewater solution as an absorber is when the concentration of the solvent used is at 14% with 1.0 l/min flow rate of biogas. $H_2S$ removal however was unable to be conducted due to its low concentration (ppm) in biogas mixtures, hence there is no significant changes in its concentration that are worth to be analyzed. Since in this technique $H_2S$ and $CO_2$ both are removed, in that case costs associated with selective removal of $H_2S$ using this technique has not yet shown competitive with other methods. Therefore, $H_2S$ removal from this technique will probably only be considered for the simultaneous removal of both $H_2S$ and $CO_2$.

## 2.5 Iron Chelation Method

Horikawa et al. (2004) investigated chemical absorption of $H_2S$ in a Fe (III)-EDTA catalyst solution. In this process, $H_2S$ is dissolved in an aqueous solution and catalytically removed by a chelated iron according to the following reaction:

$$S^{2-} + 2Fe^{3+} = S + 2\,Fe^{2+}$$

The sulfur produced is easily separated by sedimentation or filtration from the Fe-EDTA-solution. Regeneration of the aqueous Fe-EDTA-solution is done by oxygenation, followed by conversion of the pseudo-catalyst into its active form $Fe^{3+}$:

$$\tfrac{1}{2}O_2\,(aq) + 2Fe^{2+} = 2Fe^{3+} + 2OH^-$$

Due to the regeneration the Fe-EDTA-solution can be retained entirely and a large consumption of chemicals is avoided. The process can be carried out at ambient temperature and is very specific in removing $H_2S$: the volumes of the other biogas components $CH_4$ and $CO_2$ remain nearly constant. Moreover, a removal of 90-100% can be obtained for biogas containing 2.2% $H_2S$ at a gas flow of 1 $dm^3$ $min^-1$, the catalytic solution flowing at 83.6 $cm^3$ $min^-1$ and an inlet biogas pressure of 220 kPa . At lower catalytic solution flow, lower absorption efficiency is obtained. At lower inlet $H_2S$ concentration higher absorption efficiency is obtained. Therefore, the total removal of $H_2S$ depends on the use of the adequate ratio of gas to liquid flow rates.

## 2.6 Adsorption on Carbon Molecular Sieves

Granular activated carbon (GAC) is a preferred method for removal of volatile organic compounds from industrial gas streams. Heating carbon-containing materials to drive off volatile components forms GAC's, which have a highly porous adsorptive surface. Utilization of GAC's for removal of $H_2S$ has been limited to removing small amounts. If $H_2S$ is the selected contaminant to be removed, GAC's impregnated with alkaline or oxide coatings are utilized. Catalytic-impregnated, impregnated carbons and non-impregnated carbons (virgin) are the three basic types of activated carbon. Catalytic-impregnated AC is manufactured by treatment with urea or some other chemical containing nitrogen (i.e. $NH_3$). These chemicals react with the surface sites on AC particles and add nitrogen functionalities. Catalytic carbons are said to be water-regenerable. Whereas Impregnated AC is those to which a solid or liquid chemical has been mixed with carbon substrate before, during, or after activation. The main chemicals serving as impregnates are sodium bicarbonate ($NaHCO_3$), sodium carbonate ($Na_2CO_3$), sodium hydroxide (NaOH), potassium hydroxide (KOH), potassium iodide (KI), and potassium permanganate ($KMnO_4$). Mixtures of these chemicals are sometimes used. A typical $H_2S$ loading capacity for caustic, impregnated carbons is 0.15 g/g of AC. Strong base-impregnated carbons are considered regenerable by re-application of the strong base. Such regenerations are rather cumbersome for small scale applications and can lead to the spent adsorbent being classified as hazardous, including the treatment area. While non-impregnated AC employed for $H_2S$ removal has $H_2S$-loading capacities around 0.02 g/g of AC [12].

## III. RESEARCH METHODOLOGY

The *Analytic Hierarchy Process* (AHP), introduced by Thomas Saaty, is an effective tool for dealing with complex decision making, and may assist the decision maker to set priorities and make the finest decision. By reducing complex decisions to a series of pairwise comparisons, and then produce the results, the AHP helps to capture both subjective and objective aspects of a decision. As well the AHP include a helpful technique for checking the consistency of the decision maker's assessment, thus reducing the prejudice in the decision making process. The AHP considers a set of assessment criteria, and a set of alternative options among which the best decision is to be made. It is significant to note that, since some of the criteria could be different, it is not true in general that the best option is the one which optimizes each single criterion, to a certain extent the one which achieves the most suitable trade-off among the different criteria. The AHP make a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The superior the weight, the more significant the corresponding criterion. Subsequently, for a fixed criterion, the AHP allocate a score to each option according to the decision maker's pairwise comparisons of the options based on that criterion. The superior the score, the better the performance of the option with respect to the considered criterion. Finally, the AHP merge the criteria weights and the alternative scores, thus determining a inclusive score for each option, and a consequential ranking. The inclusive score for a given option is a weighted sum of the scores it obtained with respect to all the criteria.

The AHP is a very flexible and influential tool because the scores, and as a result the final ranking, are obtained on the basis of the pairwise relative assessment of both the criteria and the options provided by the user. The calculation made by the AHP are always guided by the decision maker's experience, and the AHP can thus be considered as a tool that is able to interpret the assessment (both qualitative and quantitative) made by the decision maker into a multicriteria ranking [14].

The Selection and ranking of multifaceted criteria for the Prioritization of $H_2S$ removal Techniques from Biogas in Indian Context is very crucial step of this process. Various criteria like Total Availability of Biomass, Conversion Technology, Process efficiency, Cost of Biomass Resources, Capital Cost Involved and Emission Released are selected from the literature review and discussion with experts from different sectors that are related to the problem improves the effectiveness and correctness of the decision.The alternatives will be pairwise compared with respect to the criterion for preference as shown in Fig. 1 given below.

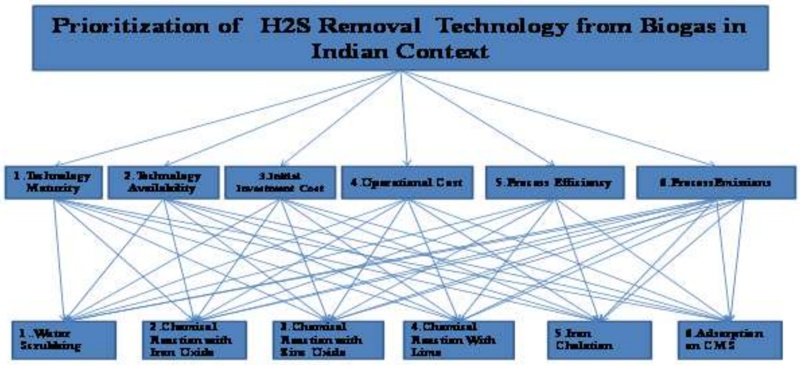


**Fig 1: The Hierarchy of H2S Removal Technologies from Biogas**

In this research SuperDecisions software designed by William J. Adams is used for the implementation for decision making. In this software a decision model is made up of clusters, nodes and links. Clusters are groupings of nodes which are logically related factors of the decision. Connections are made among nodes to establish comparison groups and when nodes are connected links automatically appear between their clusters. In a hierarchy the links go only downward: from the goal node to the criterion nodes and from each Criterion node to the alternative nodes. Priorities for the criteria are obtained by calculating the principal eigenvector of the above matrix. A short computational way to obtain this vector is to raise the matrix to powers. Fast convergence is obtained by successively squaring the matrix. The row sums are calculated and normalized. The computation is stopped when the difference between these sums in two consecutive calculations of the power is smaller than a prescribed value.

The priorities of an AHP pairwise comparison matrix are obtained by solving for the principal eigenvector of the matrix. The mathematical equation for the principal eigenvector $w$ and principal eigenvalue $\lambda max$ of a matrix $A$ is given below. It says that if a matrix $A$ times a vector $w$ equals a constant ($\lambda max$ is a constant) times the same vector, that vector is an eigenvector of the matrix. Matrices have had more than one eigenvector; the principal eigenvector which is associated with the principal eigenvalue $\lambda max$ (that is, the largest eigenvalue) of $A$ is the solution vector used for an AHP pairwise comparison matrix. $Aw = \lambda max\ w$. The *SuperDecisions* software uses a special algorithm to remember and display additional priorities in the Limit supermatrix that appeared in successive powers of the matrix and give useful information. The final overall priorities for the alternatives, in raw unnormalized form, appear in the column beneath the goal. The priorities for the criteria in the goal column, when normalized, are the original priorities derived by pairwise comparison. The weighted supermatrix is raised to powers until it converges to the limit supermatrix which contains the final results, the priorities for the alternatives, as well as the overall priorities for all the other elements in the model. It happens that the weighted supermatrix is the same as the unweighted supermatrix for an AHP hierarchy, so raise the matrix above to powers [15, 16].Below is a screenshot of the Biomass Alternatives hierarchy as it appears in the software in Fig. 2

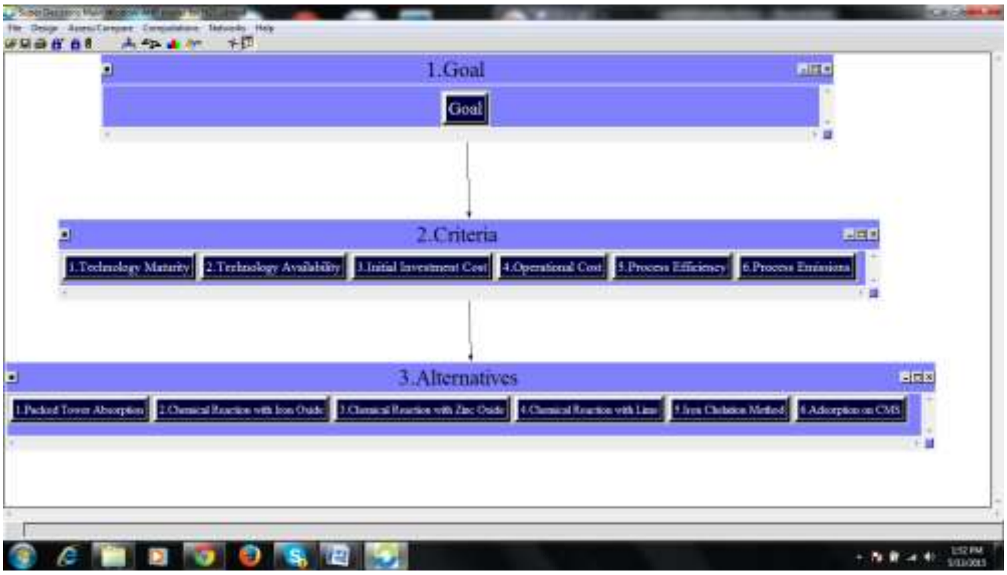


**Fig 2: The Hierarchy of Links in Super Decision Software**

The pairwise comparison judgments are made using the Fundamental Scale of the AHP and the judgments are arranged in the pairwise comparison matrix. The pairwise comparison judgments used in the AHP pairwise comparison matrix are defined as shown in the Fundamental Scale of the AHP given by Thomas Satty below in Table 1.

**Table .1: The Fundamental Scale of the AHP**

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | Two elements contribute equally to the objective |
| 3 | Moderate importance | Experience and judgment slightly favor one element over another |
| 5 | Strong importance | Experience and judgment strongly favor one element over another |
| 7 | Very strong importance | An activity is favored very strongly over another |
| 9 | Absolute importance | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Used to express intermediate values | |
| Decimals | 1.1, 1.2, 1.3, …1.9 | For comparing elements that are very close |

The numbers in the cells in an AHP matrix, by convention, indicate the dominance of the row element over the column element; a cell is named by its position (Row, Column) with the row element first then the column element. Only the judgments in the unshaded area need to be made and entered because the inverse of a judgment automatically entered in its transpose cell. The diagonal elements are always 1, because an element equals itself in importance. If the number of elements is $n$ the number of judgments is $n(n-1)/2$ to do the complete set of judgments as shown in Table-2.

**Table 2: Matrix showing Pairwise Comparison of Criteria with respect to Goal**

| Goal | 1.Technology Maturity | 2.Technology Availability | 3.Intial Investment Cost | 4.Operation Cost | 5.Process Efficiency | 6.Process Emissions |
|---|---|---|---|---|---|---|
| **1.Technology Maturity** | **1** | **3** | **4** | **5** | **4** | **7** |
| **2.Technology Availability** | | **1** | **3** | **4** | **3** | **6** |
| **3.Intial Investment Cost** | | | **1** | **2** | **4** | **5** |
| **4.Operation Cost** | | | | **1** | **3** | **4** |
| **5.Process Efficiency** | | | | | **1** | **2** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **6.Process Emissions** | | | | | | **1** |

Table 3 represents the complete pair-wise comparisons between the different parameters considered for ranking the overall priorities of $H_2S$ removal Technologies. The values of the respective criteria are entered in 6x6 matrix.

**Table 3: Matrix showing Complete Pairwise Comparison of Criteria with respect to Goal**

| | 1.C1 | 2.C2 | 3.C3 | 4.C4 | 5.C5 | 6.C6 |
|---|---|---|---|---|---|---|
| 1.C1 | 1 | 3 | 4 | 5 | 4 | 7 |
| 2.C2 | 0.333 | 1 | 3 | 4 | 3 | 6 |
| 3.C3 | 0.25 | 0.333 | 1 | 2 | 4 | 5 |
| 4.C4 | 0.2 | 0.25 | 0.5 | 1 | 3 | 4 |
| 5.C5 | 0.25 | 0.333 | 0.25 | 0.333 | 1 | 0 |
| 6.C6 | 0.142 | 0.166 | 0.2 | 0.25 | 0 | 1 |

## IV. RESULTS AND DISCUSSION

Six types of multifaceted criteria Technology Maturity (Technical Aspects Only), Technology Availability (In India), Initial Investment Cost, Operation Cost, Process Efficiency and Process Emissions (Air, Water & Ground) have been evaluated to determine the most appropriate one for the prioritization of most appropriate Technology for $H_2S$ removal from Biogas in Indian Perspective . A selection methodology based on AHP (Super Decision Software) is proposed. This methodology involves a procedure for the aggregation of expert opinion using the six selection criteria that are appropriate for India.

Experts involved in the assessment found that the Technology Maturity is the most important criteria having the priority of 0.4189 followed by the priorities of Technology Availability and Initial Investment Cost as 0.2469 and 0.1444 respectively. While other criteria Operation Cost, Process Efficiency and Process Emissions have lower scores 0.0973, 0.0575 and 0.0347 respectively.

The Results above mentioned is shown below in Fig.3, the screenshot from super decision software.

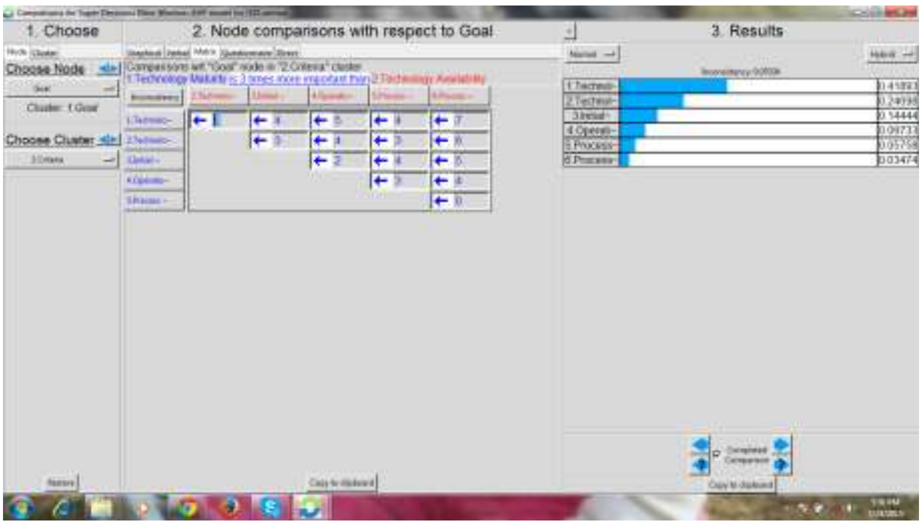


**Fig.3: The screenshot from super decision software**

The results of the above decision can also be shown as below in Table 4.

**Table 4: Priorities of Different Criteria**

Inconsistency 0.07034

| Name | Normalized | Idealized |
|---|---|---|
| 1.Technology Maturity | 0.418933375 | 1 |
| 2.Technology Availability | 0.246977191 | 0.589538112 |
| 3. Initial Investment Cost | 0.144443978 | 0.344789855 |
| 4. Operation Cost | 0.097330098 | 0.232328347 |
| 5. Process Efficiency | 0.057575502 | 0.137433553 |
| 6. Process Emissions | 0.034739856 | 0.082924537 |

It is very clear from the above results that the criteria related to **Technology Maturity and Technology Availability** are more important than any other criteria. The benefit of the proposed model is that it increases the effectiveness of the decision by allowing participation of different experts. Since decisions made in the energy sector affect all society and sectors, these decisions should not be made by the initiative of individual or through one sector.

## V. CONCLUSION

Biogas is preferred over fossil fuels sources as it is much cheaper and environmentally friendly. Gases in biogas can be combusted or oxidized with oxygen. However, before the biogas could be supplied for energy application, it needs to be cleaned and purified as there is the presence of entities like $CO_2$ and $H_2S$ which can affect the calorific value, quality, quantity and also the performance of the whole system for biogas production. Hydrogen sulfide can significantly damage mechanical and electrical equipment used for process control, energy generation, and heat recovery. The combustion of hydrogen sulfide results in the release of sulfur dioxide, which is a problematic environmental gas emission. Its removal is essential for end use of Biogas.

It was found that there are sufficient removal Technologies are available but each option has its own limitations. The Analytic Hierarchy Process (AHP) a MCDM model is an useful tool for dealing with such complex decision making. In this study an overview of various Removal Technologies of $H_2S$ from Biogas is presented and Ranking of Criteria for prioritizing various Removal Technologies of $H_2S$ from Biogas has been done. An AHP (Super Decision Software) model is developed to meet out the purpose.

From the Research, it can be concluded that the experts involved in the assessment found that in the criteria related to Technology Maturity, Technology Availability and Initial Investment Cost are more important than any other criteria. The results of this study can be useful to develop a comprehensive sustainable Energy model for a developing country like India. It should be noted that the model's application is country-specific, since the strategic criteria depend on the country's specific Biogas energy characteristics. The method used and the results obtained from this study can be used in the further research.

## REFERENCES

[1]. OECD/IEA (2010) Energy Poverty How to make modern energy access universal?

[2]. S: P. Garg, Energy Scenario and Vision 2020 in India, Journal of Sustainable Energy & Environment 3 (2012) 7-17.

[3]. Møller, H.B., Sommer, S.G. and Ahring, B.K. (2004) Methane Productivity of Manure, Straw and Solid Fractions of Manure. Biomass and Bioenergy, 26, 485-495

[4]. Eddi, W. L., & Hang, L. (2001). Analytic hierarchy process, an approach to determine measures for business performance. Measuring Business Performance, 5(3), 30–36.

[5]. Elkarmi, F., & Mustafa, I. (1993). Increasing the utilization of solar energy technologies (SET) in Jordan: Analytical Hierarchy Process. Journal of Energy Policy, 21, 978–984.

[6]. Greenlane F. Biogas upgrading; 2010.

[7]. Biogas scrubbing, compression and storage: perspective and prospectus in Indian context by S. Kapdi, V.K. Vijay*, S.K. Rajesh, Rajendra Prasad

[8]. Anerousis JP and Whitman SK, Iron sponges: still a top option for sour gas sweetening. Oil Gas J 18:71–76 (1985).

[9]. Kohl A and Neilsen R, Gas Purification, 5th edition, Gulf Professional Publishing, Houston, Texas (1997).

[10]. 10. McKinsey Zicari S, Removal of hydrogen sulfide from biogas using cow manure compost, Thesis presented to the Faculty of the Graduate School of Cornell University 1–104 (2003)

[11]. .Maizirwan mel1 , Wan Noorlaili wan muda1 Sany Izan ihsan , Ahmad faris ismail , Sarifah ,Yaacob , purification of biogas by absorption into calcium hydroxide ca(oh)2 solution , xx (2014)

[12]. Horikawa MS, Rossi F, Gimenes ML, Costa CMM, da Silva MGC. Chemical absorption of H2S for biogas purification, Braz J Chem Eng 2004;21(3):415-22

[13]. N Abatzoglou, S Boivin, A review of biogas purification processes, Biofuels, Bioproducts and Biorefining, 2009 - Wiley Online Library

[14]. Saaty, T.L., 1980. “The Analytic Hierarchy Process.” McGraw-Hill, New York.

[15]. The Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process

[16]. Thomas L. Saaty, 478 pages, RWS Publications, Pittsburgh, PA, 2011 revision, ISBN 0-9620317-6-3