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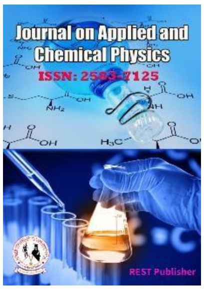

Hydrogen Energy Storage Using GRA Method

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Abstract*. This abstract introduces the notion of Hydrogen Energy Storage using the GRA (Groundwater Recharge with Aquifer Storage) approach. The GRA method includes storing hydrogen as a means of storing energy. The technique involves electrolysis to convert electrical energy into hydrogen, which is then stored for future use during moments of power shortfall. When needed, the stored hydrogen is reconverted into energy by fuel cells. This abstract shows the application of the GRA method for efficient and environmentally friendly hydrogen energy storage. The concept of hydrogen energy storage has attracted substantial interest in recent years as a viable solution for addressing the unpredictable nature of renewable energy sources. With the increasing integration of renewable energy into the power grid, there is a growing need for effective and affordable energy storage solutions. Hydrogen energy storage offers a potential answer by transforming excess electricity into gas through the process of electrolysis. This hydrogen can then be stored and employed later to produce electricity using fuel cells, offering a reliable and clean source of electricity when renewable energy generation is limited. The relevance of developing hydrogen energy storage rests in its ability to address significant issues in the integration of sources of clean energy into the power grid. As the world strives to move to a more sustainable and environmentally friendly power grid, the short-term availability of renewable provides a huge challenge. Energy storage technologies serve a significant role in bridging the gap between energy production and demand, allowing a more reliable and consistent power supply. Grey Relational Analysis (GRA) is a mathematical tool used to investigate and assess the relationships between various variables or components. It is often applied in decision-making processes and problem-solving scenarios. GRA helps analyse the degree of correlation and similarity between distinct variables, helping researchers to find the most relevant aspects or make informed decisions based on the generated grey relational grades. This strategy is particularly beneficial when working with complicated and uncertain systems, providing a quantitative approach to assessing and comparing various variables. Alternate parameters taken as Consisting of tank (A1), Metal hydride (A2), Chemical (A3). Evaluation parameters taken as Weightlessness, Capacity, Storage loss and leak, Reliability, Total system cost. Consisting of tank (A1) got 1st rank, Metal hydride (A2) got 2nd rank, and Chemical (A3) got 3rd rank. Consisting of Tank (A1) got First Rank with less compensation*.

Keywords*: Energy Storage, MCDM, GRA, Renewable energy, Capacity.*

1. INTRODUCTION

The use of hydrogen is seen as a significant energy-saving strategy that maximizes sustainable and renewable energy. In recent decades, the field of hydrogen technology has advanced rapidly. This article provides a comprehensive analysis of important technologies related to hydrogen production in a hydrogen storage facility, utilizing a combination of fossil fuels, biomass, and renewable electrical sources. Storage techniques include compressed gas, liquefied gas, material-based storage, and hydrogen-powered power generation [1]. Currently, a significant amount of energy storage is being utilized to meet oscillations in electricity demand in the power industry, which is undergoing changes due to national energy policies that aim to incorporate electricity generated from renewable sources. Technologies for generating hydrogen from fossil fuels include the partial oxidation of natural gas and steam reforming, as well as the gasification of coal and hydrocarbons [2]. Hydrogen gas is stored using various options, such as solid-state deposits like metal hydrides or chemical solvents, which offer higher storage densities. For large-scale storage systems, minimal investment costs are crucial. Hydrogen-based energy storage systems enable the use of energy storage in applications ranging from small-scale home use to enterprise-level power production, starting with kilowatt-class fuel cell applications and scaling up to hundreds of kilowatts using combustion turbines [3]. Hydrogen, the universe's lightest and most abundant element, exists primarily in combination with other elements, notably carbon and oxygen in water, nitrogen and oxygen compounds, and fossil fuels. While hydrogen is not the main source of energy, it can be separated from these components and serve as a desirable energy carrier. Hydrogen is considered a green fuel of the future, particularly for transportation and energy storage [4]. Heat storage tanks rely on compressed air, which is produced by squeezing air and removing its heat. The process involves conveying heat and applying compressive stress to steel tubes with a helical shape, followed by the application of atmospheric pressure to the storage material. In one method, a cave is filled with brine after being abandoned due to insufficient wind energy generation, and compressed air is passed through the heat storage system. The heat from the combustion chambers of a tandoor is stored at a slightly lower temperature than the exhaust temperature of the compressor [5]. It is expected that the hydrogen economy will eventually emerge as a means of adhering to a grid powered entirely by renewable energy, fulfilling the demand envisioned by many, including initiatives like California Senate Bill 100. This study establishes a model and evaluates alternatives to achieve a fully renewable source of electricity. It examines possible alternatives and their sensitivity to functional restrictions, as well as the problem of hydrogen storage and its impact on energy efficiency. Additionally, a cost estimate is provided. Several papers explore the effects of departmental consolidation, electrification in the heating industry, and decarbonization in the transportation industry [6]. The issue of harnessing wind energy on a large scale is best addressed through energy storage methods such as compressed air, compressed water, and hydrogen-based energy storage, which can lower costs and promote the integration of renewable energy. However, the latter two methods are geographically constrained, making hydrogen-based energy storage using water electrolysis a flexible option. Although hydrogen has touring advantages, longer energy saving capabilities, and quicker response times, its storage capacity is not particularly high. Hydrogen serves as an energy carrier in various significant applications [7]. With the global population and diverse energy needs, energy sources are increasingly diversifying to support sustainable growth. The energy production sector, which relies on massive centralized systems, is now witnessing an expansion in the number of distributed energy power grids with decentralized energy systems and resources. By employing more affordable and low-carbon technologies, the sector can have a small negative impact on the environment while enabling modern electrification. Traditional fossil fuels are being depleted daily, leading to concerns about environmental degradation and climate change [8]. Providing on-demand hydrogen (P2H) from a hydrogen-based gas turbine to the power grid using a hydrogen energy storage (HES) system is crucial for maintaining a balance between energy production and consumption. On the other hand, electricity users can participate in Demand Response (DR) programs to reduce their usage during peak load or when wind power is scarce, increasing their consumption when the load is low or when there is excess wind power. This helps reduce leaks and system energy expenditures associated with wind energy [9]. Hydrogen energy storage systems have been developed for portable/mobile applications, including personal energy sources and autonomous underwater vehicles. The integration of electrolysis, metal hydride, and polymer electrolyte membrane fuel cell technologies, along with increased energy density, is recommended for system integration and application-oriented design. Separating the charging and discharging mechanisms improves energy density and usability. Power sources have become more sophisticated with advancements in technology, and there has been a recent increase in the market for portable/mobile energy storage devices, particularly for low to medium power applications [10]. Hydrogen energy is undoubtedly one of the main sources of energy for the future, but there are areas that can be improved. Issues related to storage and transportation arise after producing hydrogen energy. However, these issues are expected to be resolved in the coming years through technological advancements and academic research. According to Baikara, hydrogen has limited energy and negative effects on the ecosystem and climate, but further exploration is needed by reading the second chapter in-depth. In the future, hydrogen energy is expected to replace oil as a power source for transportation, including cars, trains, and ships [11]. Hydrogen energy storage (HES) typically requires three basic components: an electrolyte, a compressed gas tank, and fuel cells. Through the process of electrolysis, electrical energy is converted into hydrogen, which is stored until there is a power shortage. The stored hydrogen is then used by fuel cells, along with oxygen from the air, to generate electricity and power the load of the power plant. This strategy enables long-term energy conservation. Various strategies are employed for hydrogen storage [12]. The term "high-temperature hydrogen" refers to firmly bonded adsorbed hydrogen in the catalyst, which can be easily evacuated, especially in the presence of inert gases. A reduced model form can be used for approximate process simulation, predicting the activation energy of crucial reactions ($E/R = 26540$ K), similar to research on similar catalysts [13]. Hydrogen is produced and consumed in large quantities as the principal energy carrier. The successful development of the hydrogen economy brings numerous benefits, including environmental, energy sustainability, and economic advantages for end users. However, gas and liquid phase storage systems pose safety and cost challenges for internal applications, limiting their potential for the hydrogen economy. Fortunately, solid-state storage systems based on metal hydrides have demonstrated significant potential for storing hydrogen safely and efficiently in large quantities. As a result, hydrogen has become an increasingly attractive option for various applications [14]. Safety is a crucial aspect throughout the design, construction, and operation phases of the system. A systematic approach to planning has enabled the design and analysis of hazards and security conditions arising from human or technological failures, as well as natural disasters. Private, regional, and government agencies have provided essential assessments and followed all relevant codes related to the system [15].

2. MATERIALS & METHODS

Alternate Parameters: Consisting of tank (A1): The phrase "consisting of tank (A1)" refers to a configuration or system that includes a specific component known as a tank, designated as A1. This indicates that the tank, represented by A1, is an essential element of the overall structure or configuration being discussed. The tank, in this context, could be an actual vessel used for storing chemicals or fulfilling a specific role within the provided system. The term "consisting of tank (A1)" implies the presence and function of the tank as part of the described arrangement.

Metal hydride (A2): The term "metal hydride (A2)" pertains to a compound or substance consisting of a metal element that has formed a chemical bond with hydrogen. In this case, A2 represents a specific metal hydride molecule. Metal hydrides are known for their ability to absorb and release hydrogen gas reversibly, making them desirable for applications in hydrogen storage and transportation. The classification A2 identifies a distinct species of metal hydride, indicating a specific composition or variety within the broader group of metal hydrides. These materials play a crucial role in hydrogen power plants and technologies, providing a means of safely storing and releasing hydrogen for various applications.

Chemical (A3): The phrase "chemical (A3)" refers to a substance or chemical that is part of a particular system or environment. A3 denotes a specific chemical within the system being examined. Chemicals encompass a wide range of substances, including elements, compounds, and mixtures, which exhibit unique characteristics and reactions based on their composition and structure. The designation A3 implies a separate chemical unit within the described setting. This specific molecule, identified as A3, may possess distinct features, functions, or responsibilities within the network or activity being discussed.

Evaluation Parameters:
Weightlessness: Weightlessness refers to the absence of gravitational forces acting on an object or individual, resulting in a sensation of feeling weightless. In this state, objects and individuals float freely and experience a lack of weight, as observed in space or during free-falling events. Weightlessness occurs when the gravitational attraction is effectively reversed or eliminated, creating a situation where the perception of gravity is reduced or nonexistent.

Capacity: The capacity of a storage tank refers to its ability to hold a specific volume or quantity of a substance, such as liquids or gases. It represents the maximum amount that the tank can accommodate. Capacity is typically measured in units of volume, such as liters or gallons, and specifies the amount of material that can be held in the tank at any given time.

Storage loss and leak: Storage loss and leak are two distinct challenges in the context of storage systems. Storage loss refers to the gradual decrease or depletion of stored material over time, which can occur due to evaporation, chemical reactions, or other factors. On the other hand, a leak refers to an unplanned and typically rapid release of stored material from a container or storage system, resulting in a loss of containment. Leaks can be caused by factors such as equipment failure, corrosion, or human error and may present safety, environmental, or economic concerns.

Reliability: Reliability refers to the quality or characteristic of being trustworthy, consistent, and dependable in terms of performance, operation, or behaviour. It is the ability of a system, device, or process to function consistently and predictably as intended under normal operating conditions, without unexpected failures or disruptions. Reliability is a crucial feature in various fields, including technology, engineering, manufacturing, and service industries, as it ensures that products or systems can be relied upon to effectively and consistently fulfils their intended functions over a specified period.

Total system cost: The total cost of a system or project is the sum of all the costs involved in its installation and operation. It encompasses all costs incurred throughout the lifecycle of the system, including initial investment, maintenance, operating costs, and any additional expenses. Calculating the total system cost is necessary to assess the financial viability and determine the economic feasibility of a project or system.

GRA Method: GRA is a developed MCDM technique that utilizes numerous statistical models and incorporates various decision-making criteria. It is effective in addressing issues that involve complex relationships among multiple variables and elements. The key step in the approach is calculating the grey equivalent rank between the reference segment and each comparative sequence. GRA is particularly useful in dealing with intricate interactions among components and variables due to its association with grey system theory [16]. However, traditional GRA techniques are insufficient in handling weight information in intuitionist fuzzy MADM issues. Obtaining attribute weights from vaguely informative intuition and limited knowledge of the data and domain is a significant area of study that requires attention. Therefore, the purpose of this work is to propose a strategy for addressing MADM issues with large amounts of information by extending the GRA concept [17].This model is commonly used for examining the interactions or relationships between variables. Its main advantage is the ability to deliver accurate results even with small sample sizes or uncertain probability distributions. Applications of the GRA model include determining important variables affecting a system, assessing the degree of connection between variables, and evaluating alternatives by comparing performance rankings with excellent line-ups. For simplicity, the weighting approach is referred to as the GRA method [18].The GRA impact assessment model measures the degree of similarities and differences between two sequences based on their relationship. The fundamental principle is that an alternative is preferred if the comparison series derived from that alternative has the highest grey relative quality compared to the reference sequence [19]. Deng first proposed the application of Grey Relational Analysis (GRA) to MCDM issues, and it has been effectively used to address numerous MCTM issues. GRA serves as a model for evaluating the influence of correlations between series, utilizing geometric methods or data analysis methods. Researchers typically select a reference series based on the magnitude of the problem under examination. This technique measures the correlation between a reference series and a comparison series. In some cases, attribute values for MADMs are derived from intuitive and hazy information, and knowledge of attribute weights is insufficient due to time constraints, lack of information or knowledge, and the expert's limited understanding of the issue [20].The feasibility of estimating the weightage of assessment indices using the GRA technique has been demonstrated. These results validate the use of the GRA approach in the weight determination process of the risk assessment department. GRA can identify close links between various sequences based on the shape of sequence curves and is suitable for handling non-linear data [21]. The correlation coefficient can determine the degree of linear association between two random components. Generally, the stronger the correlation between two variables, the more consistent their changing trend. However, the degree will be lower. GRA is utilized to create a matrix representing the correlation coefficient [22], and grey numbers are used in this technique to account for uncertainty and imperfect information. Grey numbers represent the outcome and can transform spoken ideas into numerical forms. In this essay, we evaluate and analyze various sources of renewable and non-renewable energy based on a novel simultaneous sustainability strategy. While the GRA method has been widely employed in many studies, it is important to acknowledge its limitations and shortcomings [23]. GRA proves to be useful in resolving issues involving multiple variables and intricate relationships among properties. When dealing with discrete data and imperfect information, the GRA approach is frequently employed to address uncertainty issues. It is also utilized to determine the optimal access network [24] and estimate population exposure, population knowledge, and environmental factors that affect people and the effects of geological disasters on the population [25].

3. RESULT & DISCUSSION

TABLE 1. Hydrogen Energy Storage

	Weightlessness (C1)	Capacity	Storage loss and leak	Reliability	Total system cost
Consisting of tank (A1)	55.06	150.39	36.05	22.05	50.00
Metal hydride (A2)	40.05	142.97	33.69	27.30	24.60
Chemical (A3)	67.05	122.58	29.18	23.10	155.36

Table 1 show that Hydrogen Energy Storage using GRA Method. The alternatives are consisting of tank (A1), Metal hydride (A2), Chemical (A3). The Evaluation Parameters are Weightlessness, Capacity, Storage loss and leak, Reliability, Total system cost.

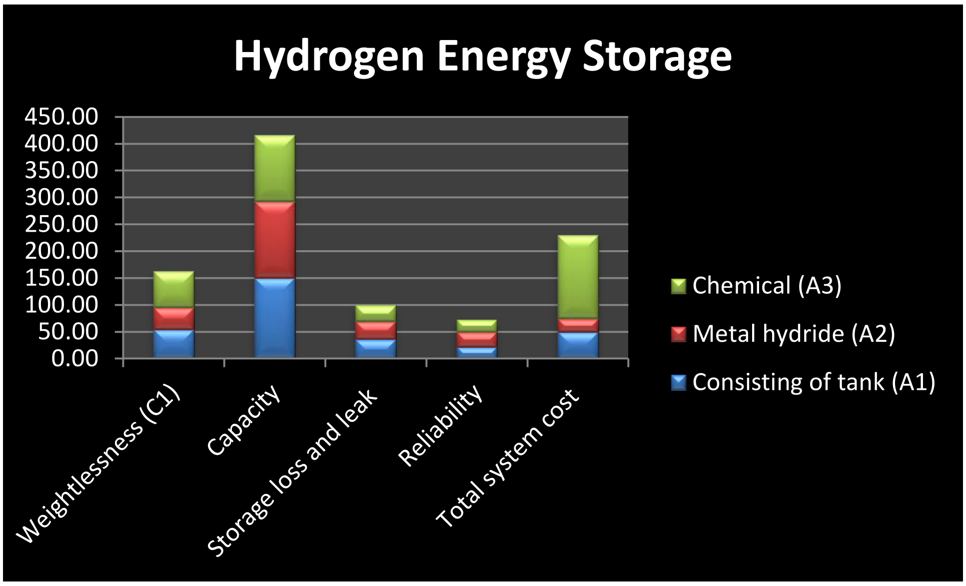

FIGURE 1. Hydrogen Energy Storage

TABLE 2. Normalized Data

	Weightlessness (C1)	Capacity	Storage loss and leak	Reliability	Total system cost
Consisting of tank (A1)	0.555926	1	1	1	0.805751
Metal hydride (A2)	0	0.73319	0.656477	0	1
Chemical (A3)	1	0	0	0.8	0

Table 2 show that the Normalized Data for all the Alternate & Evaluation Parameters.

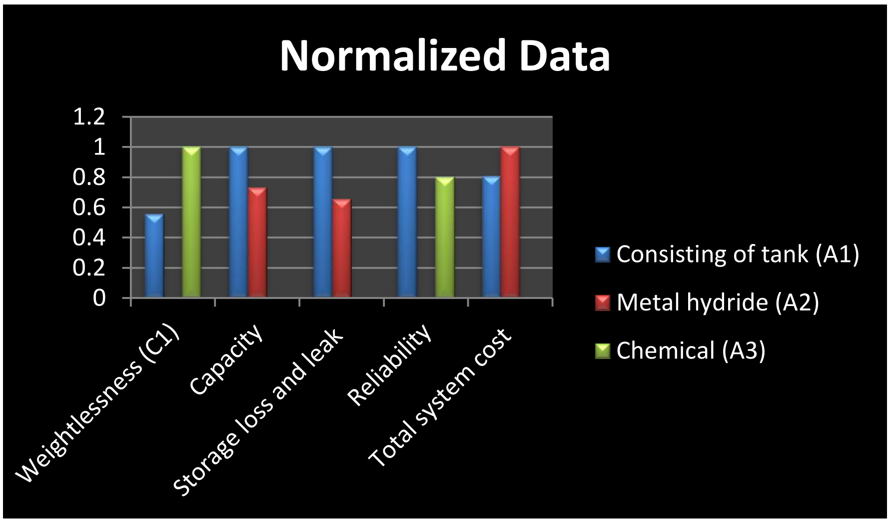

FIGURE 2. Normalized Data for Hydrogen Energy Storage

TABLE 3. Deviation Sequence

	Weightlessness (C1)	Capacity	Storage loss and leak	Reliability	Total system cost
Consisting of tank (A1)	0.444074	0	0	0	0.194249
Metal hydride (A2)	1	0.26681	0.343523	1	0
Chemical (A3)	0	1	1	0.2	1

Table 3 shows Deviation Sequence for all the Alternate & Evaluation Parameters.

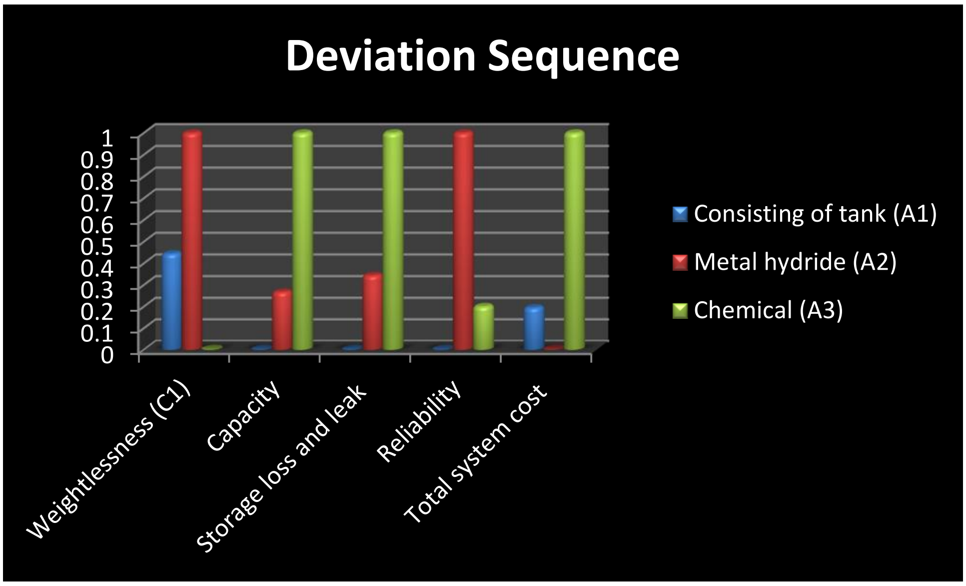

FIGURE 3. Normalized Data for Hydrogen Energy Storage

TABLE 4. Grey Relation Matrix

Grey Relation Matrix					
	Weightlessness (C1)	Capacity	Storage loss and leak	Reliability	Total system cost
Consisting of tank (A1)	0.529619	1	1	1	0.720203
Metal hydride (A2)	0.333333	0.652052	0.592752	0.333333	1
Chemical (A3)	1	0.333333	0.333333	0.714286	0.333333

Table 4 shows Grey Relation Matrix for all the Alternate & Evaluation Parameters.

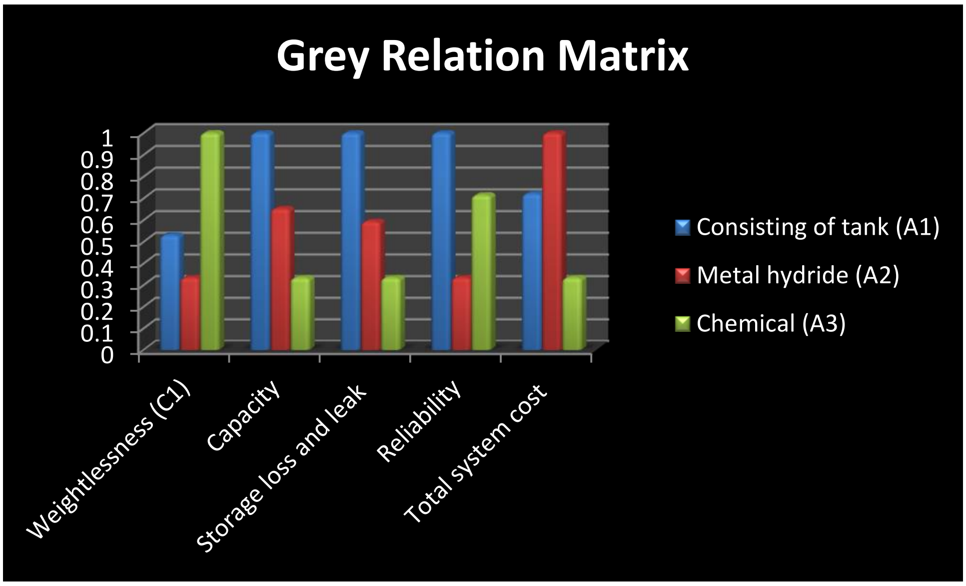

FIGURE 4. Grey Relation Matrix for Hydrogen Energy Storage

TABLE 5. CRG & Rank

	CRG	Rank
Consisting of tank (A1)	0.849964	1
Metal hydride (A2)	0.582294	2
Chemical (A3)	0.542857	3

Table 5 Shows the Consisting of tank (A1) got 1st rank, Metal hydride (A2) got 2nd rank, and Chemical (A3) got 3rd rank.

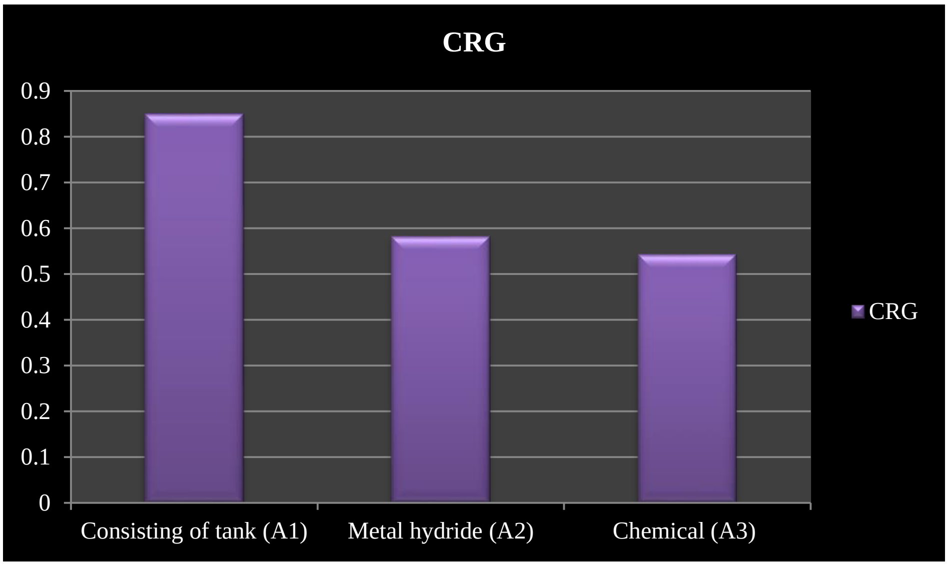

FIGURE 5.CRG Value

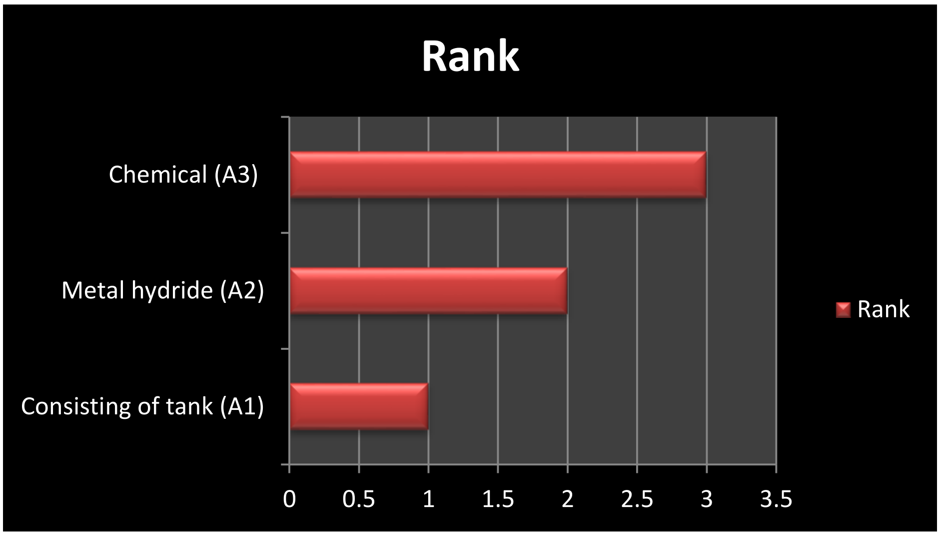

FIGURE 6.Rank

Figure 6 shows Consisting of Tank (A1) got First Rank.

4. CONCLUSION

The use of hydrogen is seen to be a significant energy-saving strategy that makes the most of energy that is sustainable and renewable. In recent decades, the field of hydrogen technology has advanced quickly. This article offers a comprehensive analysis of important technologies up to hydrogen is produced in a hydrogen storage facility utilising a combination of fossil fuels, biomass, and renewable electrical sources. Storage techniques include compressed gas, liquefied gas, material-based storage, and hydrogen-powered power generation. Already, a significant quantity of energy storage is being employed to meet energy demand oscillations in the demand for electricity power industry is changing. It seeks to supply some electricity generated from renewable sources a number of national energy policies. Technology for generating hydrogen from fossil fuels includes the partial oxidation of natural gas and steam reforming Gasification of coal and hydrocarbons. GRA is a developed MCDM technique that employs many statistical models and has various decision-making criteria. GRA works well for resolving issues involving intricate relationships between numerous variables and elements. Calculating the grey equivalent rank among the reference segment and each comparative sequence is the major step in the approach.GRA is useful for resolving issues involving complicated interactions between numerous components and variables because it is a component of grey system theory. The degree of linear association between two random components can be determined by the correlation coefficient. In general, the stronger the correlation between two variables, the more constant their changing trend is. The degree will be lower, however. GRA was used to create the matrix representing the correlation coefficient. As a Result, Table 5 Shows the Consisting of tank (A1) got 1st rank, Metal hydride (A2) got 2nd rank, and Chemical (A3) got 3rd rank.

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