# Prioritization Thermochemical Materials based on Neutrosophic sets Hybrid MULTIMOORA Ranker Method

**Mona Mohamed[1], Nissreen El Saber [2]**

[1]Higher Technological Institute, 10th of Ramadan City 44629, Egypt

[2]Faculty of Computers and Informatics, Zagazig University, Zagazig 44519, Egypt

Emails: mona.fouad@hti.edu.eg; naelsaber@fci.zu.edu.eg

**Abstract**

Present era, several technologies are combining in various industries to strengthen sustainable ecological, economic, and societal. For example, in storage energy industrial where a sophisticated technique for storing thermal energy called thermal energy storage (TES) can lessen the effects on the environment and enable cleaner and more effective energy systems. Particularly, thermochemical energy storage (TES) which is characterized by substantial density of energy. So, selecting suitable material among the set of materials is crucial process. This study emphasized employing durable techniques to elucidate complex interrelationships between criteria and several materials. Thus, this study employs Multi-criteria Decision Making (MCDM) methods. Also, we are supporting these methods with robust theory represents in neutrosohic theory to fortify MCDM methods in uncertainty and non-aligned situations. Moreover, we are utilizing Multi-objective Optimization by Ratio Analysis plus Full Multiplicative Form (MULTIMOORA) assists with Single Value Neutrosophic sets (SVNs). Finally, we applied our constructed framework to a real case study to guarantee that our framework is accurate and valid.

**Keywords:** Thermochemical; Material Selection; MULTIMOORA; Neutrosophic Sets; with Single Value Neutrosophic sets (SVNs)

## 1. Introduction

Recent investigations have shown that both industrial and academic research are now heavily focused on energy storage [1]. This is as a result of [2] expected that the world's energy demand is rise by 50% between 2005 and 2030, due to population expansion and economic development. Another perspective as [3] describes energy storage's alternatives which permit for the storage of surplus energy and subsequent use of that energy when the system requires it have gained importance recently. Also, others confirmed that via [4],[5] where future low-carbon energy systems might benefit over the long run from the utilization of creative and efficient energy storage methods. Admitted that [6] whereas energy policy aims to decarbonize the energy system and boosting energy efficiency by switching to other energy sources, creating new energy production technologies. Other motivations represented in [7] for developing and adopting advanced energy technologies is the negative effects on the environment brought on by rising energy use, such as air pollution and climate change. Whilst Greenhouse gas (GHG) emissions are the primary driver of climate change.

Various studies as [8] adopted miscellaneous energies as the sun, geothermal heat, hydroelectric power, and wind are fall under the umbrella of renewable energy sources (RESs) which become more prevalent in the world's energy systems. As stated in [9] where RESs have ability to supply energy needs today and in the future with less negative environmental effects than conventional non-RESs. According to [10] RESs capable of meeting human energy demands through a plentiful, sustainable, and long-lasting energy source as solar radiation energy. Yet based on [11] , Solar energy is intermittent, which restricts its ability to be used on a big scale, such as in concentrated solar power (CSP) facilities. Generally[12] epitomized major obstacle to effective energy storage and use is the intermittent and variable nature of solar energy.



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As a result, the researchers resorted to methods and technologies that contribute to boosting the contribution of different types of renewable energy in the energy either regions or countries. For example [13] , utilizing a thermal energy storage technology (TEST) that can store extra heat during idle operation and release it when solar radiation is insufficient or nonexistent is a great way to ensure the continued functioning of CSP facilities. Likewise [14] described TEST as one of technologies that holds tremendous promise for storing thermal energy and for balancing the fluctuations in both demand and supply brought on by the intermittent nature of popular renewable energy sources.

TEST encompasses different methodologies heat as sensible TES (STES), latent TES (LTES), and thermochemical TES (TCTES) that serve to store solar see Ref [15] for more details about these methodologies. Han et al**.,** [16] reported that comparing LTES and STES systems, TCTES systems have energy storage densities that are up to five and fifteen times greater, respectively. The storage time and transport distance of TCES systems are also potentially limitless. This is as a result of the TCES's traits that [10] described as:

- Large-scale energy storage in smaller occupation of spaces.
- A broad operational range of temperature accompanied by affordable thermal drive costs.
- The need for thermal insulation can be decreased since vast volumes of energy can be transferred and stored for a long time.
- Energy-efficient, ecologically friendly, and vibration- and noise-free.
- When deciding on input and output temperatures, TCTES systems provide more flexibility.
- TCTES's thermophysical properties, cyclability, and safety.

Despite the fact that TCTES systems have recently gained prominence as a viable method for storing solar thermal energy [17]; Depending on perspective of [18] it is quite difficult to choose the right TCTES for a given process, because to the differences between the materials' quantitative and qualitative qualities. So,[19] affirmed that for selecting the best candidate material for application, the material selection process plays a significant role and necessitates the clarification of complicated interrelationships between the many criteria and aspects.

Given that there has been a substantial amount of research as [20] on the process of selecting materials nowadays, researchers have developed viable techniques and tools for this utilization. By way of a point of view [21] the alternative materials can be appraised in light of set of criteria. Thus, the material selection problem could be considered a multiple criteria decision-making problem that can be tackled using the MCDM approach.

Shahinour et al**.,** [22]described criteria information for alternative materials as ambiguous and imprecise because human perception is hazy and material qualities are unpredictable and indeterminate. These obstacles are challenging for Mathematical approaches of MCDM to treat with such environment which characterized with uncertainty or imprecise.

Subsequently, there are many scholars who attempted to solve such obstacles by reinforcing MCDM approaches Fuzzy sets (FSs) which proffered by Zadeh [23] and [24] merging FSs with MCDM to construct ( FMCDM); Atanassov [25] enhanced of FSs through introducing intuitionistic fuzzy sets (IFSs) which able to measure the degree of membership, non-membership, and hesitancy; until generalization of FSs and IFSs demonstrated in neutrosophic theory which proffered by Smarandache [26]. This theory takes into consideration three functions of membership, indeterminacy, and non-membership. As a result, this theory is widely used and implemented to enhance decision-making in various disciplines[27]–[29].

Moreover, this study attempts to take advantage of ability of neutrosophic theory to treat with uncertainty situations, especially single-valued neutrosophic set (SVNs) for constructing sturdy hybrid mathematical framework so-called "Ranker Neutro-Multi- Criteria Decision Framework"[30], [31]. The main purpose of the study's framework achieves through performing set of stages as in Figure 1. Also, Multi-objective Optimization by Ratio Analysis plus Full Multiplicative Form (MULTIMOORA) is applied with support of AHP to get criteria's weights of alternatives. This study consolidated two utilized MCDM methods by SVNs.



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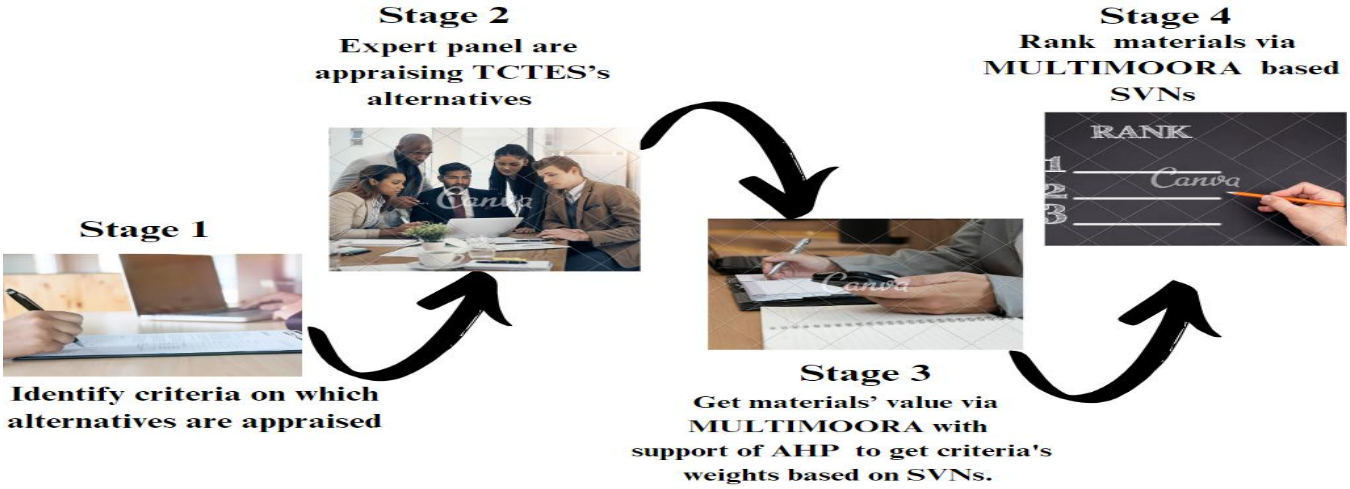


Figure 1: Comprehensive view of the stages of the

This study's contribution is best summed up as the stages are outlined and indicated in Figure 1as following:

- Hypothetically and theoretically:
  - Through the survey of related literature studies which have been performed, we acquainted with the types of TES and its benefits. Also, its impact on preserving the environment to be cleaner especially thermochemical storage (TCS) which is of interest in this study.
  - Determining shortcomings of literature studies and our study attempt to release it.
  - Determining the most effective criteria where these criteria based appraising process as mentioned in stage 1of Figure 1.
- Practically**:**
  - Organizing an expert panel who participates in appraising process for alternatives (materials) as in Figure 1 (At stage 2).
  - Selecting suitable techniques which participate in constructing framework.
  - Utilizing MULTIMOORA with assists by AHP of MCDM and merging an effective technique to strengthen selected MCDM techniques in uncertainty situation. Moreover, SVNs merged with MULTIMOORA - AHP to develop "Ranker Neutro-Multi- Criteria Decision Framework" (See stage 3 in Figure 1).
  - According to stage 4 in previous Figure, "Ranker Neutro-Multi- Criteria Decision Framework" generates rank for selected alternatives to identify most benefitable/best alternative and worst one.

- Validity:
  - Firstly, comparing our constructed framework with others.
  - Secondly, applying "Ranker Neutro-Multi- Criteria Decision Framework" on real case study to validate framework's efficiency.

The paper organizes into several sections, each one introduces certain information as overall view about this study is represented in introduction section; the previous studies which related to our interested area is involved in the basic principles and techniques associated with our passionate pursuit section; therefore, section three solving the problem of materials selection through constructing robust framework. Moreover, it is important to validate the constructed framework, so section four is embracing this point. And our conclusion is formulated in the conclusion section. Finally, our future proposals regarding this area are included in the future direction.



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## 2. The basic principles and techniques associated with our passionate pursuit.

This section involves previous studies which related to our interested area; whether in terms of basic and theoretical concepts as well as the methods that were used to evaluate the alternatives.
So, it divides into two sub sections as follows.

### 2.1 Principles of Thermochemical thermal energy storage

Many scholars [32], [33] are described chemical of heat storage with various expressions as chemical storage, thermochemical storage and sorption. TCTES [16] have recently gained prominence as a viable method for storing solar thermal energy which has the characteristics of high energy storage density and theoretically limitless storage time, is a promising technique for ensuring the continuous operation of CSP facilities. Based on [34] TCTES improved cycle stability and greater thermal conductivity.

During the process of thermochemical power storage, energy is first stored during a dissociation response, and then it is restored during a reaction that is chemically in opposite. Thermochemical storage has a storage density according to [35],[36] which is larger than other forms of TES, which means that it is capable of storing huge amounts of energy. Thermochemical increasing the internal, in this regard, provide much greater storage capabilities per mass or volume in comparison to reasonable or inborn heat storage.

Essentially [37], admitted that a material's data on heat storage capacity depends on its characterization scale for material, reactor, and system. TCTES's materials are classified as in Figure 2 for more details (see Ref [37]).

### 2.2 Role of Mathematical approaches in material's selection

Several academics have used MCDM to tackle a variety of material selection issues**;** the strongest argument in favor of broadly employing MCDM is table 1. The number of missteps while choosing materials may be reduced thanks to MCDM, which also offers a rigorous, rational, and repeatable technique that can be used in a broad range of circumstances.

Greatest frequently, the user's preferences govern the selection of the most appropriate materials for a certain operation, which involves a variety of crucial steps including evaluating and selecting the materials.



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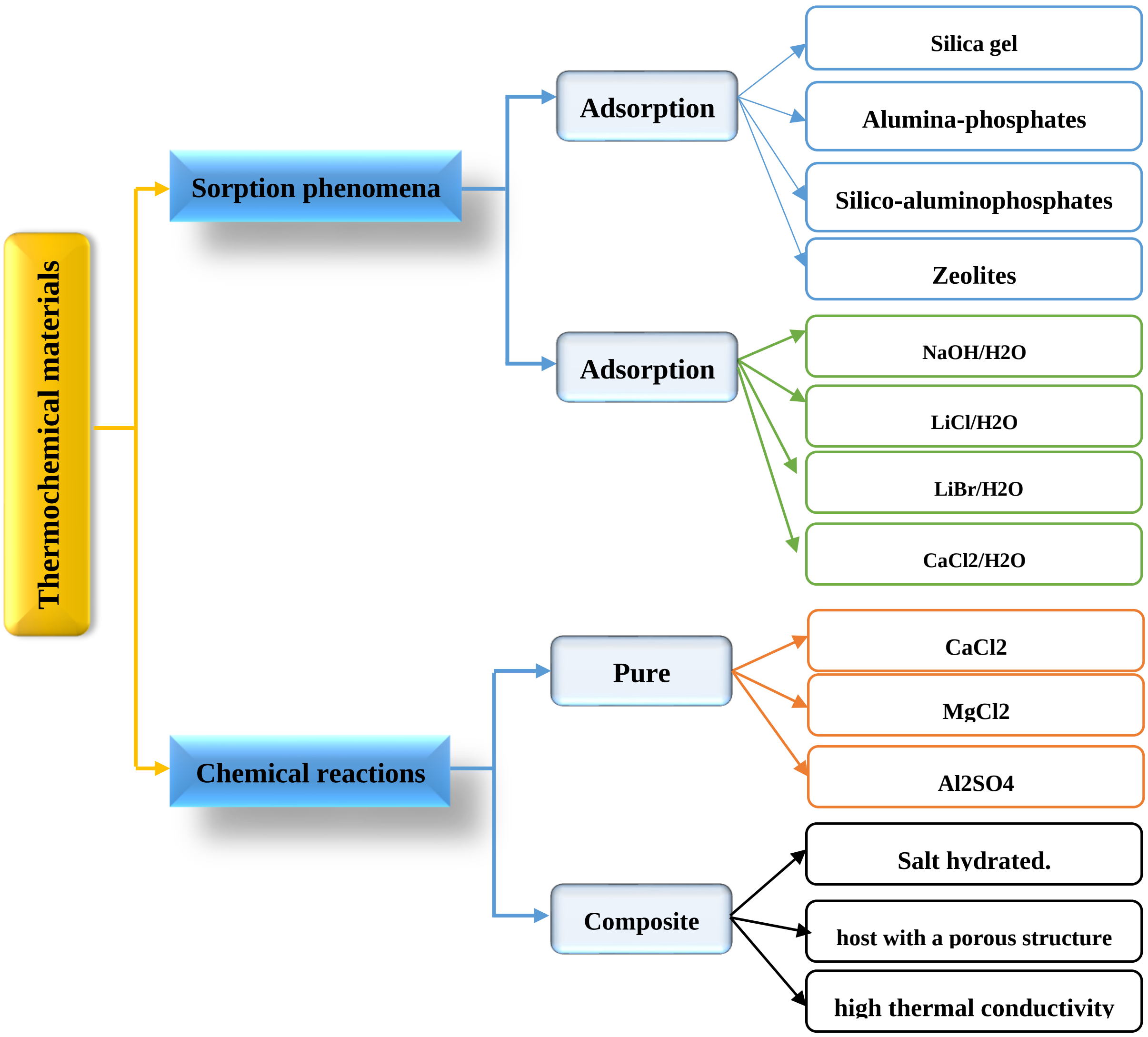


Figure 2: Classification of thermochemical energy storage

Table 1: An extensive study of pertinent past studies in the field of interest

| Ref # | Utilized Techniques | Objective |
|---|---|---|
| Shanian et al.,, [38] | Elimination and Choice Expressing REality (ELECTRE) | -ELECTRE has been utilized to produce a material choice decision matrix and conduct a requirements sensitivity analysis to achieve a material choice that is more accurate for a given application.<br>-ELECTRE's results demonstrated that the used tool is a useful for identifying an appropriate material for a specific application of a loaded thermal conductor. This application required a material that could effectively transfer heat. |



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| | | |
|---|---|---|
| Hambali et al. [39] | Analytic Hierarchy Process AHP method | -AHP is applied for selecting suitable material to prevent predicament of recreated or remanufactured when choosing an inappropriate material. |
| Gaddala et al., [40] | AHP and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) | -a mixed MCDM technique is used to choose the most suitable phase change materials PCMs.<br>-AHP is used to determine the subjectivity of the weights associated with each characteristic.<br>-TOPSIS used for ranking of the PCMs. |
| Liu et al., [41] | VIekriterijumsko KOmpromisno Rangiranje (VIKOR) | -Utilizing VIKOR to handle materials selection challenges. In order to choose the best material for a specific application |
| Peng et al., [42] | PROMETHEE (Preference Ranking Organization Methods for Enrichment Evaluations) and analytic network process (ANP). | -The combined MCDM techniques are used for choosing the bes[43]t material for a particular application. |
| Loganathan et al [43] | TOPSIS, VIKOR, and PROMETHEE methods were integrated with a fuzzy | -The integrated model used in electronics cooling system through selecting PCM. |
| Tian et al. [44] | AHP, grey correlation and TOPSIS | - The goal of integrating several techniques for remedying to problems with choosing green decorating materials, |
| Sa et al.[45] | Fuzzy TOPSIS and Fuzzy AHP | - Solve the issue with the green materials section through merging two different techniques based on uncertainty technique FSs. |
| Girubha et al. [46] | Fuzzy VIKOR | - The applied technique us deciding on the best material for electrical instrument plates |

According to our survey, which is shown in Table 1, several fuzzy set types have been introduced and used to address MCDM problems. Yet, it is not possible for these approaches to account for all the numerous types of uncertainty that could arise in addressing real-world engineering difficulties.

This study attempts to remediates MCDM methods' shortcomings through following the study of [47] through utilizing MCDM methods under technique which able to strengthen and improve it.

This environment depicts a neutrosophic theory that may absorb different assessments for decision-makers by describing their judgements based on degrees of true, indeterminate, and false.

In light of this, we are constructing our framework through using AHP and MULTIMOORA and reinforcement it through merging it with neutrosophic theory (SVNs) and work under this theory.

## 3. Ranker Neutro-Multi- Criteria Decision Framework

The operations and maintenance functionality of SVNs algebra and the conventional crisp AHP and MULTIMOORA methods will be fused together as the core of the suggested technique in order to create its essential essence [43]–[44]. The building of the decision problem is the initial step in the suggested technique, just as it is in the majority of the MCDM methods. The components of this matrix each constitute the $\boldsymbol{a_{ij}}$ ith requirements of the jth potential solution[45], [46].

### 3.1 Identification Process

In this stage we performing several steps as following:



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1. we identify set of TCTES's materials which represents as alternatives ($\boldsymbol{A_n}$). Whereupon we decide which criteria ($\boldsymbol{C_n}$) are most important in determining how well TCTES works as an energy storage material.
2. After that, we classify determined ($\boldsymbol{C_n}$) into benefitable and non-benefitable.
3. Equip the group of decision makers (GoDMs) who analyze ($\boldsymbol{A_n}$) and ($\boldsymbol{C_n}$) are determined in this problem. The main role of (GoDMs) is appraising determined ($\boldsymbol{A_n}$) and ($\boldsymbol{C_n}$).

### 3.2 Valuation criteria's weights

We are utilizing the most effective and popular MCDM methodology, the AHP method. Its role in this stage is calculating the subjective weights ($\boldsymbol{C_n}$) as in following steps:

4. The formed (GoDMs) assigns ratings to the determined ($\boldsymbol{C_n}$) according to saaty scale as in [54].
5. Transforming these ratings into neutrosophic pairwise comparison matrices as formed in Eq. (1).

$$\boldsymbol{Rating_{DM_n}} = \begin{pmatrix} {cr^n}_{11} & {cr^n}_{12} & \cdots & {cr^n}_{1n} \\ \vdots & & \ddots & \vdots \\ {cr^n}_{n1} & {cr^n}_{n2} & \cdots & {cr^n}_{mn} \end{pmatrix} \quad (1)$$

6. De-neutrosophic pairwise comparison matrices based on Eq.(2). Then Eq.(3) performed for accumulating these matrices into one matrix called accumulator matrix .

$$s(cr_{ij}) = \frac{(2 + T_{ij} - I_{ij} - F_{ij})}{3} \quad (2)$$

Where symbols of $T_{ij}, I_{ij}, F_{ij}$ indicated to truth, indeterminacy, and falsity, $cr_{ij}$ refers to the value of each criterion in the comparison matrix.

$$\boldsymbol{Acc_{ij}} = \frac{\sum_{n=1}^{n} {cr^n}_{ij}}{n} \quad (3)$$

Where $\boldsymbol{n}$ is members of (GoDMs).

7. The role of Eq. (4) is normalizing accumulator matrix.

$$Nor\_matrix_{ij} = \frac{s_j}{\sum_{j=1}^{m}(s_j)}, \mathrm{j} = 1,2, \dots \dots \mathrm{m} \quad (4)$$

Where $\sum_{j=1}^{m}(s_j)$ sum of factors per column in accumulator matrix, $s_j$ refers to preference of criterion in accumulator matrix.

8. The following Eq. (5) is obtaining criterion's weight through summation of each raw and divide each result by number of criteria in matrix.

$$w_i = \frac{\sum_{i=1} \; Nor\_matrix_{ij}}{M} \quad (5)$$

Where $\sum_{i=1} \; Nor\_matrix_{ij}$ sum of criteria per raw in normalized matrix, $M$ is number of criteria.

9. The formed Eq. (6) utilized for Checking the consistency ratio (CR) with assists of Eq.(7)

$$CR = \frac{CI}{RI} \quad (6)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (7)$$

### 3.3 Ranking and selecting optimal TCTES's materials

The ratio system is the first goal that the neutrosophic MULTIMOORA technique aims to accomplish. For the purpose of determining this goal, we are applying several steps as:



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1. Constructing decision matrices based on preferences of (GoDMs); transform these matrices into neutrosophic matrices.
2. De-neutrosophic the constructed decision matrices and aggregated it into mono -matrix.
3. Normalizing mono-matrix using a method known as vector normalization [47] by following Eq.

$$\boldsymbol{NA} = \frac{\boldsymbol{a_{ij}}}{\sum_{i=1}^{m} \boldsymbol{a_{ij}}} \quad (\mathbf{8})$$

4. Utilizing Eq. (9) for generating weighted normalized mono-matrix.

$$w\_nor_j = \sum_{i=1}^{g} w_i * NA_{ij} \quad (9)$$

5. Estimation of assessment values ($Ass_i$ ) based on following Eq.

$$Ass_i = \sum_{i=1}^{g} w\_nor_j - \sum_{i=g+1}^{n} w_{nor\,j} \quad (10)$$

Where g refers to the beneficial criteria and n refers to non-beneficial criteria.

6. Ranking $A_n$ based on the values of $Ass_i$ and select optimal one.

## 4. Validation of Ranker Neutro-Multi- Criteria Decision Framework

The purpose of this section is validating our constructed framework through utilizing several methods. So, it divides into two subsections; each one is intended to carry out a particular mission. First subsection is representing in applying our framework in real case study. Second sub section is comparing our ranker framework with other ranker methods as Topsis and VIKOR

### 4.1 Application of proposed Ranker framework

In order to serve as a numerical example, the evaluation of the material selection is carried out. This section divided into two parts. First part includes the values of criteria's weights generated from utilizing AHP method under govern of SVNs. Second part is ranking set of $A_n$ and MULTIMOORA based on SVNs is recommending the optimal alternative among $A_n$. This study performs the experiment for two MCDM under govern of SVNs on 8 criteria and 5 alternatives as shown in Figure 3. The 8 criteria are evaluated by decision makers. The weights method used to compute the weights of criteria. Moreover, The criteria's weights of AHP are organized as: $w1 = 0.142327782, w2 = 0.077964531 = w3 = 0.167083507, w4 = 0.102720256, w5 = 0.127475981, w6 = 0.134901882, w7 = 0.11262418, w8 = 0.134901882$.

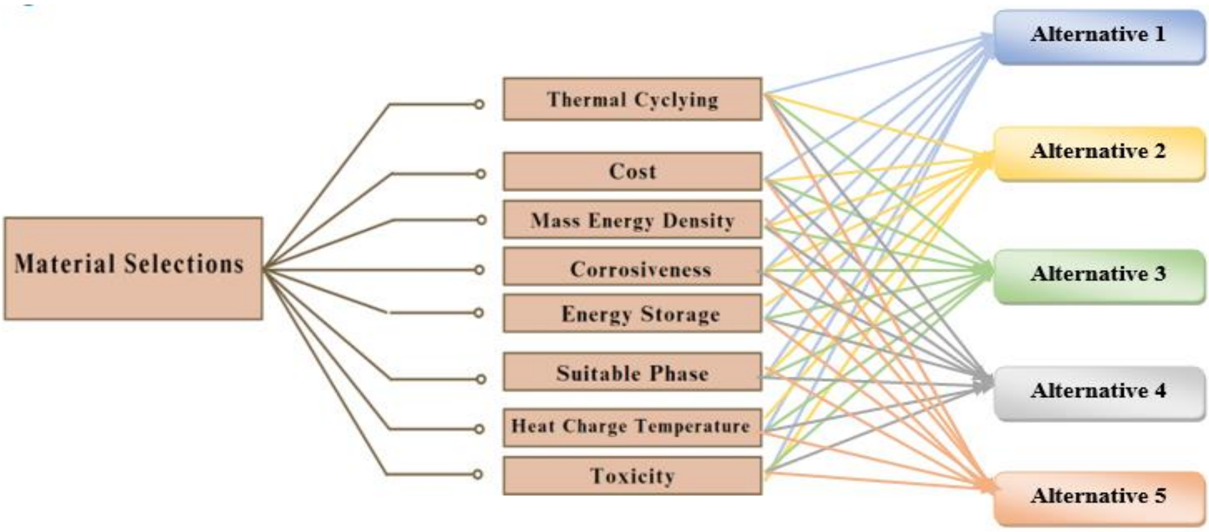


Figure 3: The relationship between criteria and alternatives.



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The decision makers evaluate the criteria and alternatives to build the decision matrix. Then normalize the decision matrix Table 2 is a presentation of the normalization neutrosophic decision matrix that was produced. Table 3 shows the weighted normalized decision matrix.

Table 2: The normalization decision matrix.

| | $TCTE_{C1}$ | $TCTE_{C2}$ | $TCTE_{C3}$ | $TCTE_{C4}$ | $TCTE_{C5}$ | $TCTE_{C6}$ | $TCTE_{C7}$ | $TCTE_{C8}$ |
|---|---|---|---|---|---|---|---|---|
| $TCTE_{A1}$ | 0.140039448 | 0.313433 | 0.092199 | 0.249484536 | 0.184762 | 0.308534 | 0.112871 | 0.173034 |
| $TCTE_{A2}$ | 0.278106509 | 0.147122 | 0.229314 | 0.2 | 0.28 | 0.111597 | 0.255446 | 0.258427 |
| $TCTE_{A3}$ | 0.140039448 | 0.257996 | 0.148936 | 0.224742268 | 0.12 | 0.212254 | 0.176238 | 0.191011 |
| $TCTE_{A4}$ | 0.203155819 | 0.147122 | 0.271868 | 0.142268041 | 0.245714 | 0.199125 | 0.291089 | 0.204494 |
| $TCTE_{A5}$ | 0.238658777 | 0.134328 | 0.257683 | 0.183505155 | 0.169524 | 0.16849 | 0.164356 | 0.173034 |

The ratio system aims of the SVNs based MULTIMOORA method to the alternatives is performed.

Table 3: The values weighed normalization.

| | $TCTE_{C1}$ | $TCTE_{C2}$ | $TCTE_{C3}$ | $TCTE_{C4}$ | $TCTE_{C5}$ | $TCTE_{C6}$ | $TCTE_{C7}$ | $TCTE_{C8}$ |
|---|---|---|---|---|---|---|---|---|
| $TCTE_{A1}$ | 0.019931504 | 0.024437 | 0.015405 | 0.025627115 | 0.023553 | 0.041622 | 0.012712 | 0.023343 |
| $TCTE_{A2}$ | 0.039582283 | 0.01147 | 0.038315 | 0.020544051 | 0.035693 | 0.015055 | 0.028769 | 0.034862 |
| $TCTE_{A3}$ | 0.019931504 | 0.020115 | 0.024885 | 0.023085583 | 0.015297 | 0.028633 | 0.019849 | 0.025768 |
| $TCTE_{A4}$ | 0.028914717 | 0.01147 | 0.045425 | 0.01461381 | 0.031323 | 0.026862 | 0.032784 | 0.027587 |
| $TCTE_{A5}$ | 0.033967774 | 0.010473 | 0.043055 | 0.018849696 | 0.02161 | 0.02273 | 0.018511 | 0.023343 |

Table 4 displays the outcomes of the neutrosophic reference point objective calculations for the various options that were taken into consideration.

Table 4: The values of neutrosophic reference point.

| | $TCTE_{C1}$ | $TCTE_{C2}$ | $TCTE_{C3}$ | $TCTE_{C4}$ | $TCTE_{C5}$ | $TCTE_{C6}$ | $TCTE_{C7}$ | $TCTE_{C8}$ |
|---|---|---|---|---|---|---|---|---|
| $TCTE_{A1}$ | 0.019650779 | -0.01396 | 0.03002 | 0 | 0.012141 | 0 | 0.020072 | 0.01152 |
| $TCTE_{A2}$ | 0 | -0.001 | 0.00711 | 0.005083 | 0 | 0.026567 | 0.004014 | 0 |
| $TCTE_{A3}$ | 0.019650779 | -0.00964 | 0.02054 | 0.002541 | 0.020396 | 0.012988 | 0.012935 | 0.0090 |
| $TCTE_{A4}$ | 0.010667566 | -0.001 | 0 | 0.011013 | 0.004371 | 0.01476 | 0 | 0.0072 |
| $TCTE_{A5}$ | 0.005614508 | 0 | 0.00237 | 0.006777 | 0.014083 | 0.018892 | 0.014273 | 0.0115 |

Table 5 displays the results of applying the neutrosophic complete multiplicative form goal to the many possibilities that were taken into consideration.

Table 5: The values of neutrosophic full multiplicative from

| | $\boldsymbol{Y(X_j)}$ | $\boldsymbol{Y(Z_j)}$ | $\boldsymbol{ASS_j}$ |
|---|---|---|---|
| $TCTE_{A1}$ | 2.28888E-12 | 0.024437 | 9.36659E-11 |
| $TCTE_{A2}$ | 1.67918E-11 | 0.01147 | 1.46394E-09 |
| $TCTE_{A3}$ | 2.5651E-12 | 0.020115 | 1.27525E-10 |
| $TCTE_{A4}$ | 1.4606E-11 | 0.01147 | 1.27338E-09 |
| $TCTE_{A5}$ | 5.85073E-12 | 0.010473 | 5.58657E-10 |



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The dominance theory was used to undertake the task of summarizing all of the goals that were attained via the neutrosophic MULTIMOORA method, and the findings are provided in Table 6. Figure 4 shows ranking of the alternatives.

Table 6: The final rank of alternatives.

| | Ratio system (RS) | Reference point (RP) | Full Multiplicative form (FMF) | Final rank |
|---|---|---|---|---|
| $TCTE_{A1}$ | 2 | 1 | 1 | 1 |
| $TCTE_{A2}$ | 5 | 4 | 5 | 5 |
| $TCTE_{A3}$ | 1 | 2 | 2 | 2 |
| $TCTE_{A4}$ | 4 | 3 | 4 | 4 |
| $TCTE_{A5}$ | 3 | 5 | 3 | 3 |

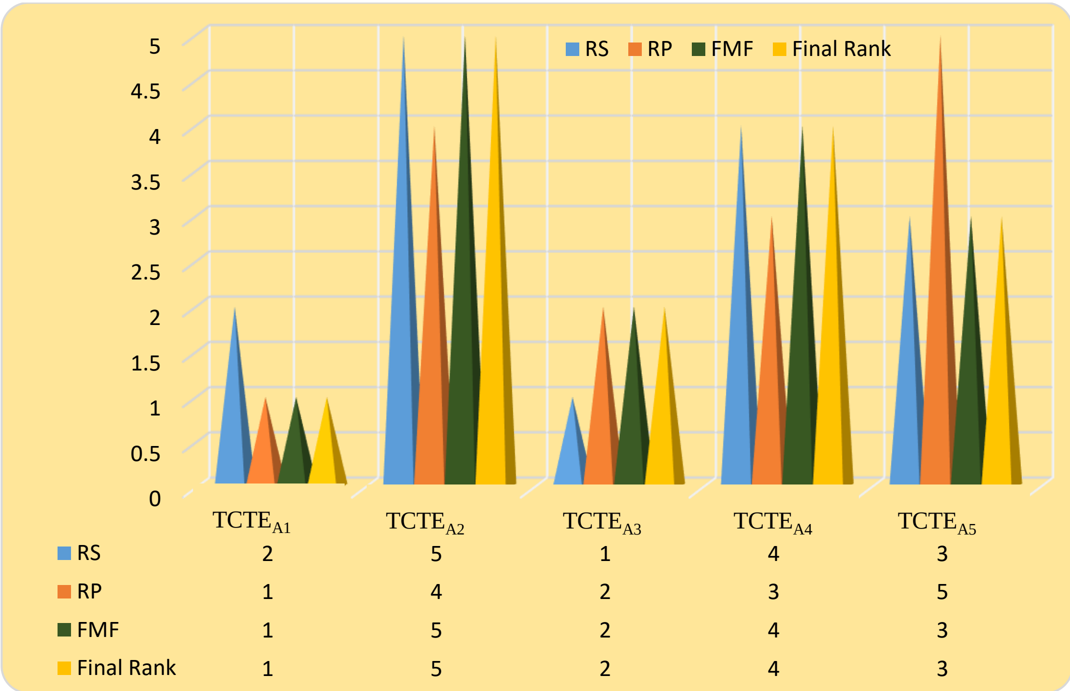


Figure 4: Rank of five options under dominance theory.

### 4.2 Comparative Analysis

In this subsection we applied other ranker methods as comparative methods with our ranker framework. These methods are represented in TOPSIS and VIKOR. The TOPSIS and VIKOR are put in interval valued neutrosophic sets and compared with the proposed methodology. Table 7 shows the comparative study between the proposed methods and comparative methods. The two comparative methods are accepted the alternative 1 (A1) is the best alternative. The proposed methodology is a robust farmework.

Table 7: The rank of three methods.

| | Proposed Method | TOPSIS Method | VIKOR Method |
|---|---|---|---|
| $TCTE_{A1}$ | 1 | 1 | 1 |
| $TCTE_{A2}$ | 5 | 5 | 4 |
| $TCTE_{A3}$ | 2 | 2 | 2 |
| $TCTE_{A4}$ | 4 | 3 | 5 |
| $TCTE_{A5}$ | 3 | 4 | 3 |



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## 5. Conclusions

The process of storing low-temperature energy requires careful consideration in the selection of a suitable thermochemical material, abbreviated TCTES. An incorrect selection of TCTES not only reduces the effectiveness of the storage system but also has negative effects on both the environment and human health. In this article, numerous various TCM options are compared and contrasted using a variety of MCDM-weighting methodologies. These comparisons are made with regard to the various criteria that play a role in the decision-making process, including concentration, power storage specific gravity, specific heat, consistency, toxicity, corrosiveness, and price. In this investigation, the MCDM MULTIMOORA was used to assess the various options based on their respective weights under neutrosophic sets to overcome the uncertainty information. The use of the MCDM approach in conjunction with neutrosophic sets is providing substantial results, and this tool, which is both simple and effective, is being used to choose the best TCTES option out of a number of potential candidates. This approach may also be used for the choice of additional materials for high temperature thermal energy storage by making use of thermochemical material, a thermo-chemical conversion process, and a PCM-based thermal energy storage system.

## 6. Future Direction

Through the performed survey for previous studies, we concluded the importance of selecting and utilizing suitable material for energy storage. So, it is crucial to communicate selection of optimal materials with the concept of sustainability and get relation between each other. This relation can clarify though determining and selecting optimal and best material based on criteria. The identification process for these criteria will be perform based on the three pillars which related to sustainability as environmental, economic, and social. After that, utilizing several techniques to appraise and judge the identified materials based on its criteria. Then the selection process will be performed and the alternative fulfilling the sustainability criteria the most will be chosen.

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