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TrSo-BHARAT-V1 Recommender Model: Toward Eco-friendly Energy Based on Optimal Installation for Solar Hydrogen Production

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Abstract

Amidst the drive for a sustainable future and the rising worries about climate change. Furthermore, the need for clean, non-polluting energy sources has become a worldwide concern due to the environmental problems brought on by the ongoing usage of fossil fuels, which are the primary cause of global warming. Evidently have recently been several methods for producing hydrogen with fuel that comes from both non-renewable and renewable sources. Hence, this study is embracing the notion of generating hydrogen energy might be a viable approach to generating energy sustainably. Accordingly, the modern techniques are harnessing for constructing robust recommender model for analyzing and evaluating the possible sites for solar hydrogen production and estimating the optimal site. The evaluation process is conducted through analyzing a set of factors and sub-factors. Hence, we are leveraging Tree soft approach (TrSoA) for modelling these factors and sub-factors into nodes are resident into levels. Moreover, the best Holistic Adaptable Ranking of Attributes Technique (BHARAT) is utilized for evaluating candidates of sites based on factors and sub-factors which modelled into TrSoA. Finally, the modern two techniques are merged for constructing tree soft recommender model (TrSoReM) towaed recommend optimal site for solar hydrogen production.

Keywords: Solar, Hydrogen Production, Tree Soft Approach, Best Holistic Adaptable Ranking of Attributes Technique.

1 | Introduction

Currently, greenhouse gas emissions (GHGs) from fossil fuels are the primary cause of global warming, a severe problem that humanity cannot afford to ignore[1]. The demand for clean and sustainable energy solutions is urgent since it is necessary for maintaining socioeconomic growth, reducing greenhouse gas emissions, and achieving energy independence[2]. From perspective of [3] by using renewable energy, people may reduce their reliance on fossil fuels for energy and achieve "dual carbon" objectives. Hence [4], hydrogen is one sustainable energy source that may be obtained using both renewable and fossil fuels. It functions as a possible route of energy transportation.in the same vein [4] demonstrated that Hydrogen is a sustainable energy source that can be produced from fossil fuels as well as renewable ones. It serves as one potential means of transferring energy. Whilst [5] it is possible to realize the carbon-free or carbon-less future that

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employs H_2 as a green energy carrier by taking into account its multiple applications. The increase in green H_2 production will reduce the amount of gray or blue H_2, which will lower GHGs. Accordingly and based on [6], Hydrogen is a clean and environmentally friendly energy source that can help achieve the Sustainable Development Goals (SDGs) that is because of [7] demonstrated that hydrogen generates three times as much energy while having no negative environmental impacts, compared to fossil fuels.

Due to the ability of hydrogen to: (i) H_2 can enhance the availability of clean water and sanitation by means of systems driven by renewable energy [8].(ii) In order to promote inexpensive and clean energy access, hydrogen offers a sustainable energy source that can be utilized for a variety of purposes, such as the production of electricity and fuel for vehicles [9], [10].(iii) also, investments in hydrogen [11] have the potential to boost the economy and create good jobs in a variety of industries. (iv) as hydrogen replaces fossil fuels in a variety of areas [12], it contributes to the reduction of greenhouse gas emissions and the fight against climate change.

Generally speaking, the authors in [13] stated that the creation of hydrogen has become a viable technique for storing energy in a range of applications. Now, solar hydrogen production projects (SHPPs) are getting a lot of attention and align quite well with the idea of "dual carbon."

Given the importance of solar hydrogen production, various scholars are conducted various studies to ascertain the optimal sites for the deployment of solar hydrogen production plants. In order to select the optimal site, there are many aspects that should be taken into consideration. For instance [14] stated that the various benchmarks should be used for a variety of factors, such as social, economic, environmental, and technological. Confirmation of that [15] examined the location of solar hydrogen production from the perspectives of the economy, environment, dust, flood jeopardy and land costs.

Thereby, this study exploited these influenced factors to evaluate the possible sites and recommend optimal site. Toward conducting the evaluation process, we are harnessing various novel techniques. Each utilized technique has a crucial role for conducting the evaluation for candidates of sites for solar hydrogen production. For instance, we are exploiting Tree Soft Approach (TrSoA) where this approach introduced by Smarandache [16] who is also the founder for neutrosophic theory. Thus, TrSA is leveraging for modelling the influenced key factors and sub-factors into set of nodes which resident into set of levels. Furthermore, BHARAT one of the latest MCDM techniques is utilizing in this study for analyzing the nodes of key factors and sub-factors which modelled into TrSoA and then ranking the candidates of sites and recommend optimal and worst sites.

2 | Literature Review: General Perspectives for Estimating Solar Hydrogen Production Sites

This section investigates and aggregates previous studies and techniques which harnessed in scope which like study's scope.

The siting of solar hydrogen production plants according to [17] takes into account a number of factors, and it is critical to determine how these factors relate to one another. In order to ascertain the effect, share of the criterion and the ranking order of the alternatives, MCDM offers a methodical manner to integrate choice criteria with decision makers' opinions.

As an illustration, Kannan et al.[18] merged VIse Kriterijumski Optimizacioni Racun (VIKOR) with the Best-worst Method (BWM) to determine criteria weights and evaluate the locations of solar power plants in eastern Iran. Weighted Aggregated Sum Product ASsessment (WASPAS), Stepwise Weight Assessment Ratio Analysis (SWARA) and COmplex PRoportional Assessment of alternatives (COPRAS) are employed in [19] for analyzing criteria and obtaining its weights and determine the locations for solar hydrogen production plant in Uzbekistan.in the same vein of [18], Demir et al. utilized AHP as similar technique of BWM in [20] to determine the weights of the criteria and identify Turkey's best solar power farms. Also, Geographic Information Systems (GIS) applied with BWM in [21] to determine the best sites for the installation of solar-wind hybrid renewable energy systems in Bangladesh and to determine the weights of the criteria. ANP-VIKOR was used by Lee et al. [22]to determine criterion weights and evaluate potential sites for solar energy plant development in Taiwan, China.

Generally speaking, we are investigating the ability of MCDM to treat conflicting criteria in our problem. Hence, BHARAT is utilizing in our problem to recommend optimal site based on set of factors and sub-factors which are modelling into TrSoA. These factors and sub-factors are forming as nodes are resident into levels. Moreover, these techniques are contributing to constructing tree soft recommender model (TrSoReM) where these techniques and model are illustrated in next section.

3 | Methodology: Recommending Optimal Location of Solar Hydrogen Production

Firstly, we are illustrating the basic concepts of utilized techniques in our study.

3.1 | Tree Soft Approach (TrSoA)

It is the generation of a series of random numbers that follow a uniform distribution over the field $[0,1]$, and then converting these random numbers into random variables that follow the distribution according to which the system to be simulated operates. There are many techniques used to generate these random numbers, such as the mean square, the product mean., the Fibonacci method and others, and to generate neutrosophic random numbers we presented a study in the research [18] and we used the mean square method and we reached the following results:

The concept of TrSA is proposed by Smarandache [16] where the main attributes of this approach are described as following:

Let $\mathfrak{H}$ be a universe of discourse, and $\mathcal{H}$ a non-empty and subset of $\mathfrak{H}$, whilst the powerset of $\mathcal{H}$ denoted as P($\mathcal{H}$).

- Main nodes encompass main attributes/criteria/factors and symbolled as $\mathfrak{R}$. Accordingly, $\mathfrak{R}$ has set of $\mathfrak{R}_s$ with (one-digit indexes) = $\{\mathfrak{R}_1, \mathfrak{R}_2, \ldots \mathfrak{R}_n\}$.
- Sub-nodes which have two-digit indexes and symbolled as: $\{\mathfrak{R}_{11}, .. \mathfrak{R}_{1n}\}$ are sub-nodes of $\mathfrak{R}_1$, $\{\mathfrak{R}_{21}, .. \mathfrak{R}_{2n}\}$ are sub-nodes of $\mathfrak{R}_2$, and $\{\mathfrak{R}_{31}, .. \mathfrak{R}_{3n}\}$ are sub-nodes of $\mathfrak{R}_3$.
- Generally, a graph-tree is formed, that we denote as Tree(ℵ), whose root is considered of level zero, then nodes of level 1, level 2, up to level n.
- We call leaves of the graph-tree, all terminal nodes (nodes that have no descendants). Then the TreeSoft Set is: F: P(Tree(ℵ)) → P($\mathcal{H}$).
- All node sets of the TreeSoft Set of level m are: Tree(ℵ) = {ℵi1 | i1= 1, 2, ... }.

3.2 | BHARTA MCDM Technique

The objective of this technique in our study is to analyze factors and sub- factors which modelled in our TrSoA to evaluate alternatives and select best and worst one.

Hence, we are showcasing the basic concepts of this technique. Also, we are showcasing the implementation of BHARAT toward ranking and recommending optimal alternatives through following instructions in [23].

(i). When DMs rank alternatives based on three influenced criteria:

- Reciprocal of reciprocal of rank 1: 1/ (1/1) = 1.0.
- Reciprocal of reciprocals of ranks up to 2: 1/(1/1 + 1/2) = 0.67.

- Reciprocal of reciprocals of ranks up to 3: 1/(1/1 + 1/2 + 1/3) = 0.55

Moreover, Summation of three criteria' rank =1.0+0.67+0.55=2.22. criteria's summation employed by dividing each value of rank by criteria's summation to obtain **criteria's Average weights.** For instance:

- Rank 1 is assigned Average Weight value as: value of reciprocal of reciprocal of rank / Summation of three criteria'srank = 1.0/2.22=0.45.
- Rank 2 is assigned Average Weight value as: value of reciprocal of reciprocal of rank / Summation of three criteria's rank = 0.67 /2.22=0.302.
- Rank 3 is assigned Average Weight value as: value of reciprocal of reciprocal of rank / Summation of three criteria's rank = 0.55/2.22=0.248.

(ii). When DMs rank alternatives based on N of influenced criteria:

- Reciprocal of reciprocals of ranks up to X: 1/(1/1 + 1/2 + 1/3+…..+1/X) = Value of reciprocal of reciprocals of X.

Hence, Summation of N criteria's rank =1.0+0.67+0.55+…. +Z= Total summation of rank N criteria. Where, Z= Value of reciprocal of reciprocals X.

- Rank X is assigned Average Weight value as: Value of reciprocal of reciprocals of X/ Total summation of rank N criteria.

(iii). The "best" alternative for each attribute—beneficial or non-beneficial is used to normalize the Average quantitative value assigned.

(iv). Total scores of the alternative are computing through multiplying alternative's normalized value by Average weight value assigned to the attributes (w_i).

Herein, we are solving the problem of recommending and selecting the optimal location of solar hydrogen production through constructing tree soft recommender model (TrSoReM). Accordingly, TrSoReM is constructed into three phases.

3.3 | Proposed Merged Techniques Toward TrSoReM

The objective of this technique in our study is to analyze factors and sub- factors which modelled in our TrSoA to evaluate alternatives and select best and worst one.

Phase 1. Elucidation key factors and sub-factors into modelling of TrSoA.

1.1 A nominee of sites which are evaluating and recommending the optimal site by constructed TrSoReM.

1.2 In our problem the evaluation for sites is conducting according to Key factors and its inherent sub-factors. Hence, these factors and sub-factors are elucidating according to TrSoA.

Phase 2: Appreciating and extracting factors weights based on BHARAT-V_1.

2.1 Extracting Factors' weights.

2.1.1 Constituting panel of experts who are relevant to our problem to evaluate sites based on modelled factors in TrSo.

2.1.2 Construction of decision matrix for rating alternatives with soft scale based on factors. After that calculating the average of experts' judgements per factor.

$$\text{Averege} = \frac{\text{DM}_{1+}\ \text{DM}_{2+\cdots\ldots\ldots+\text{DM}_\text{n}}}{\text{n}} \tag{1}$$

Where n is the number of DMs.

2.1.3 According to values of average in Eq. (1), Xi-best value for each factor is determining.

2.1.4 Factors' ranks are assigned according to approach is mentioned in [24, 25].

- Thus, we construct a new decision matrix that involves experts' rating for factors and calculating average experts' judgements for each factor.
- Ranking or arranging average of judgements from largest to smallest value.
- The average factor's weights are calculated according to Eqs. (2) &(3):

$$\partial = \sum_{i=1}^{i} \frac{1}{x_j} \quad (2)$$

$$\boldsymbol{\omega_i} = \frac{1/\partial}{\sum_{i=1}^{m} 1/\partial} \quad (3)$$

where x_j indicates to rank of factor, $\boldsymbol{\omega}$ indicates the factor's weight.

2.2 Extracting factors' weights.

2.2.1 Expert panel are rating sub factors which modelled into TrSo in nodes of level 2. The evaluation is conducted based on utilizing soft scales.

2.2.2 The preceding phase for obtaining factors' weights are repeated for obtaining sub-factors' weights.

Phase 3: Ranking the alternatives of sites and recommending the optimal site.

3.1 The normalized value for each value of expert's average from Eq. (1) is calculated by divided by $x_{i\text{-best}}$ for beneficial factor as in Eq. (4).when factor is non-beneficial , Eq. (5) is applied.

$$\text{Normalized value} = \frac{x_i}{x_{i-\text{best}}} \quad (4)$$

$$\text{Normalized value} = \frac{x_{i-\text{best}}}{x_i} \quad (5)$$

3.2 Eq. (6) is utilized for obtaining the total scores.

$$\wp = Normalized\ value * \ \boldsymbol{\omega_i} \quad (6)$$

Where$\boldsymbol{\omega_i}$ is factor 's weights from Eq. (3)

3.3 The sites of solar hydrogen production are ranking according to values of $\wp$ from Eq. (6).

4 | Methodological Illustration

The objective of this section is to validate the accuracy of our constructed TrSoReM in a real case study. Hence, four sites are mentioned in our study to utilize in this section as alternatives have been evaluated based on a set of factors and sub-factors which are modelled into TrSoA as in Figure 1. Also, five experts contribute to the constitution of panel to rating the determined sites according to key factors and sub-factors which determined as in [26] .Generally speaking, our constructed model is implemented in the real case study as following:

4.1 Expert panel are rating the sites based on factors and sub factors in Figure 1.

4.2 Firstly, the panel is rating the sites based on factors according to scale in [22].and average of panel's rating is obtaining in Table 1 based on Eq. (1).

4.3 Based on values of average of panel's in Table 1, $x_{i\text{-best}}$ are determined with considering all factors are beneficial.

4.4 Accordingly, Eq. (4) is implemented to obtain normalized values and Table 2 is generated.

4.5 In other direction, we calculated weights of factors according to Eq. (3) and weights are generated in Table 3.

4.6 Total scores for each site is calculated by Eq. (6) and the results are listed in Table 4.

4.7 Accordingly, ranking of alternatives of sites are calculated and showcased in Figure 2. Site 1 is the optimal one otherwise site 4 is the worst.

4.8 Expert panel rating alternatives based on sub-factors in level 2 and average of expert rating are calculated by Eq. (1).

4.8.1 The steps for obtaining total score for sites based on factors are repeated (steps from 4.3 to 4.7) and Table 5 illustrated average rating for panel to rank sites based on sub-factors ($F_{1\text{-}1}$, $F_{1\text{-}2}$, $F_{1\text{-}3}$) in level 2. Table 6 includes normalized values and score values. Thereby, Figure 3 showcases site 1 is optimal but site 4 is the worst.

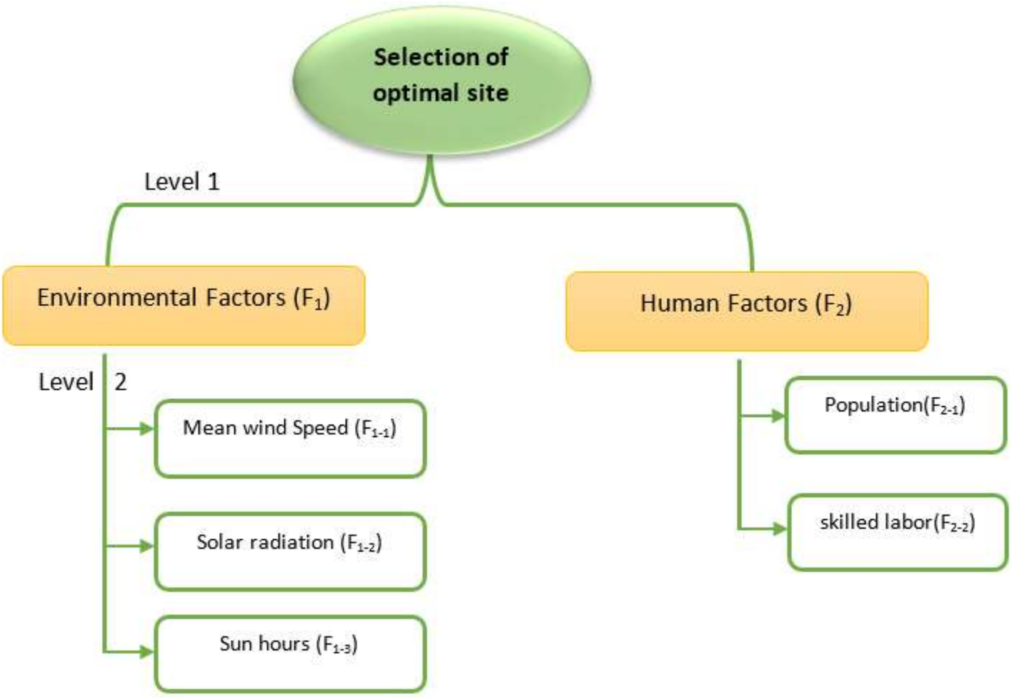

Figure 1. Modelling factors and sub-factors into Tree Soft.

Table 1. Average expert panel rate for factors at Level 1.

Key Factors	Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average of Expert s
F1	Site 1	0.6666	0.5	0.3333	0.5	0.3333	0.46664
	Site 2	0.8333	0.3333	0.6666	0.3333	0.6666	0.56662
	Site 3	0.3333	0.5	1	0.8333	0.3333	0.59998
	Site 4	0.3333	0.1666	0.3333	0.1666	0.5	0.29996
F2	Site 1	1	0.3333	0.8333	1	0.8333	0.79998
	Site 2	0.5	0.8333	1	0.3333	0.5	0.63332
	Site 3	0.6666	0.6666	0.5	0.1666	0.3333	0.46662
	Site 4	0.3333	1	0.3333	0.8333	0.1666	0.5333

Table 2. Normalized values of average expert rate.

Key Factors	Alternatives	Average of experts	Normalized value (xji/xi.best)
F1	Site 1	0.46664	0.777759259
	Site 2	0.56662	0.944398147
	Site 3	0.59998	1
	Site 4	0.29996	0.499949998
F2	Site 1	0.79998	1
	Site 2	0.63332	0.791669792
	Site 3	0.46662	0.583289582
	Site 4	0.5333	0.666641666

Table 3. Weights of factors.

Factors	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average	Rank	Reciprocal of reciprocals of rank	weighted
F1	0.666	0.833	0.5	0.5	0.666	0.633	2	0.666666	0.39999976
F2	0.833	1	0.833	1	1	0.9332	1	1	0.60000024

Table 4. Total Score.

Key Factors	Alternatives	ω_i	Scores = **Normalized value** $* \ \omega_i$
F1	Site 1	0.39999976	0.31110352
	Site 2	0.39999976	0.37775903
	Site 3	0.39999976	0.39999976
	Site 4	0.39999976	0.19997988
F2	Site 1	0.60000024	0.60000024
	Site 2	0.60000024	0.47500207
	Site 3	0.60000024	0.34997389
	Site 4	0.60000024	0.39998516

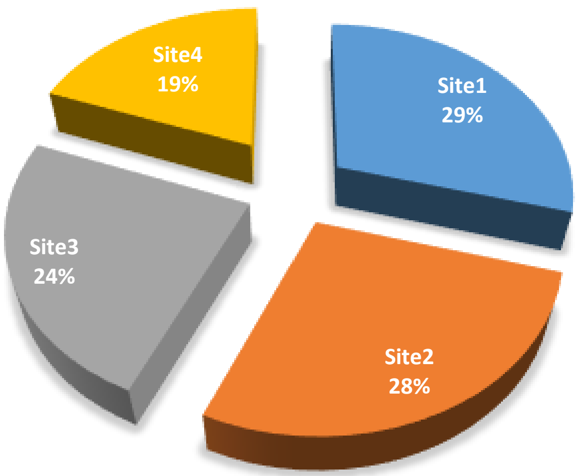

Figure 2. Ranking of sites based on factors in level 1 of TrSo.

Table 5. Average expert panel rate for sub- factors at Level 2.

Sub-Factors	Alternatives	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average of Expert s
F1-1	Site 1	0.83	1	0.5	0.83	0.66	0.764
	Site 2	0.5	0.83	0.33	0.83	0.66	0.63
	Site 3	0.66	0.5	0.66	0.16	0.83	0.562
	Site 4	0.16	0.33	0.83	0.5	0.33	0.43
F1-2	Site 1	1	0.66	0.83	0.5	0.83	0.764
	Site 2	0.83	1	0.5	0.66	0.66	0.73
	Site 3	0.5	0.33	1	0.33	1	0.632
	Site 4	0.33	0.83	0.33	0.83	0.5	0.564
F1-3	Site 1	0.83	0.66	0.5	0.33	0.16	0.496
	Site 2	0.16	0.5	1	0.83	0.66	0.63
	Site 3	1	0.33	0.66	0.66	1	0.73
	Site 4	0.16	0.66	0.5	1	0.5	0.564

Table 6. Score values at Level 2.

Sub-Factors	Alternatives	Average of Experts	Normalized value (xji/xi.best)	ω_i	Scores = Normalized value* ω_i
F1-1	Site 1	0.796	1	0.120300596	0.120300596
	Site 2	0.63	0.791457286	0.120300596	0.095212783
	Site 3	0.562	0.706030151	0.120300596	0.084935848
	Site 4	0.43	0.540201005	0.120300596	0.064986503
F1-2	Site 1	0.764	1	0.180451074	0.180451074
	Site 2	0.73	0.955497382	0.180451074	0.172420529
	Site 3	0.632	0.827225131	0.180451074	0.149273663
	Site 4	0.564	0.738219895	0.180451074	0.133212573
F1-3	Site 1	0.596	0.816438356	0.099248091	0.081029948
	Site 2	0.63	0.863013699	0.099248091	0.085652462
	Site 3	0.73	1	0.099248091	0.099248091
	Site 4	0.564	0.77260274	0.099248091	0.076679347

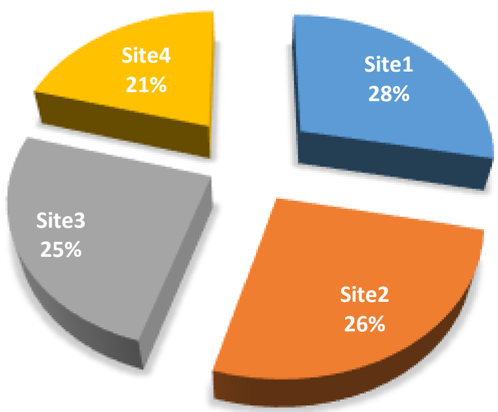

Figure 3. Ranking of sites based on sub-factors in level 2 of TrSo.

4.8.2 The steps for obtaining total score for sites based on factors are repeated (steps from 4.3 to 4.7) to rank sites based on sub-factors (F2-1, F2-2) in level 2 and average of panel's rate illustrated in Table 7. Table 8 includes normalized values and score values. Thereby, Figure 4 showcases site 1 is optimal but site 4 is the worst.

Table 7. Average expert panel rate for sub- factors at Level 2.

Sub-Factors	Alternatives	Expert1	Expert 2	Expert 3	Expert 4	Expert 5	Average of Expert s
F2-1	Site 1	0.83	0.66	1	0.5	0.66	0.73
	Site 2	0.5	0.83	0.33	1	0.5	0.632
	Site 3	1	0.16	0.66	0.33	0.83	0.596
	Site 4	0.16	0.33	0.83	0.16	0.5	0.396
F2-2	Site 1	1	0.83	0.66	0.5	0.83	0.764
	Site 2	0.5	0.83	0.5	0.16	1	0.598
	Site 3	0.16	0.33	0.83	0.33	0.66	0.462
	Site 4	0.33	0.66	0.33	0.16	0.5	0.396

Table 8. Score values at Level 2.

Sub-Factors	Alternatives	Average of Experts	Normalized value (xji/xi.best)	ω_i	Scores = Normalized value* ω_i
F2-1	Site 1	0.73	1	0.239999952	0.239999952
	Site 2	0.632	0.865753425	0.239999952	0.20778078
	Site 3	0.596	0.816438356	0.239999952	0.195945166
	Site 4	0.396	0.542465753	0.239999952	0.130191755
F2-2	Site 1	0.764	1	0.360000288	0.360000288
	Site 2	0.598	0.782722513	0.360000288	0.28178033
	Site 3	0.462	0.604712042	0.360000288	0.217696509
	Site 4	0.396	0.518324607	0.360000288	0.186597008

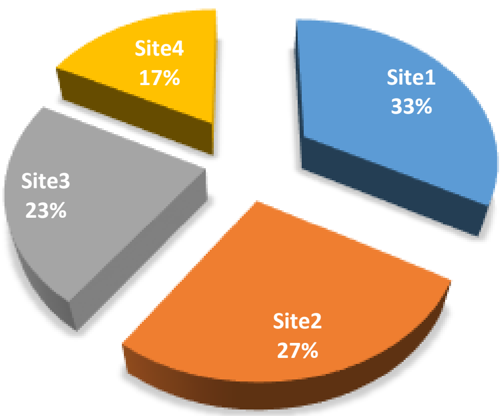

Figure 4. Ranking of sites based on sub-factors in level 2 of TrSo.

5 | Conclusions

Regarding the pursuit of carbon neutrality where the goal of the 2009 National Energy Strategy is to reduce the environmental effect of energy use by creating large-scale, diverse, and reasonably priced renewable energy sources. It is generally acknowledged that using solar power to address the world's rising energy needs is both economical and environmentally beneficial.

Hydrogen production using renewable energy sources, such solar and wind, provides a solution to cut greenhouse gas emissions and lessen the impact on the environment. Hence, Hydrogen's adaptability, high energy density, and potential for zero-emission uses have made it an intriguing alternative energy source.

In keeping with the significance of using hydrogen to mitigate environmental hazards and attain sustainability, one crucial step in the deployment of solar hydrogen generating plants is identifying the optimal sites for these installations. Consequently, our constructed TrSoReM is leveraged for evaluating the possible sites based on two main factors that are represented into TrSoA at level 1 into node 1(F_1) and node 2 (F_2). Whilst sub-factors are formed into level 2 into various nodes as F_{1-1}, F_{1-2}, F_{1-3} branched from F_1 also, nodes of F_{2-1}, F_{2-2} branched from F_2 .After that, BHARAT is applied to evaluate sites based on factors and sub-factors into TrSoA.

The findings indicated that site1 > site 2 > site 3 > site 4 where site 1 is the optimal and site 4 is the worst site.

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Author Contributaion

All authors contributed equally to this work.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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