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An Integrated BWM-TOPSIS-I Approach to Determine the Ranking of Alternatives and Application of Sustainability Analysis of Renewable Energy

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Abstract: The purpose of this paper is to identify the most significant alternatives of renewable energy sustainability using a hybrid decision-making model of multiple criteria. Sustainable energy sources cannot run out and can be used for an indefinite period of time. In addition to meeting our energy needs, sustainable energy does not need to be renewed or replenished, nor does it pose any threat of being wrong or running out. Our energy demands can only be met by renewable energy. The bestworst methodand technique for order preference by similarities to ideal solution-I processes have proposed a hybrid model named the bestworst method—technique for order preference by similarities to ideal solution-I, for this purpose. This study uses comparative analysis and sensitivity analysis to determine the results of the proposed study.

Keywords: BWM; TOPSIS-I; renewable energy; sustainability

MSC: 90B50

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1. Introduction

Sustainable development is currently at the forefront of global discussion. In many aspects of society, producing, distributing, and consuming non-renewable fossil fuels are seen as the primary causes of non-sustainability. According to expert studies (IPCC 2007), emissions from the energy sector are causally related to climate change, underscoring the need to develop more sustainable energy systems. A major step towards society's eco-restructuring goals will be achieved if the energy mix is diversified in favor of renewable energy sources (RESs) and consumption is reduced significantly.

A sustainability study of RESs is presented in this paper using multi-criteria decision making (MCDM). MCDM is used in this study to determine which RESs more reliable, because the last few centuries have seen the exploration and use of fossil fuels such as coal, oil, and natural gas as a source of electricity. The high energy density of these energy sources is their greatest advantage. Their use, however, releases carbon dioxide and other greenhouse gases. According to a report published by the International Energy Agency, global energy consumption will increase by 56% from the 2010 levels by 2040 [1]. RESs can be more easily accessed and used in the energy sector if fossil fuels are reduced and fossil fuels are expanded. RESs are frequently seen as emission-free and eco-friendly energy sources. Though RESs are a huge improvement over fossil fuels, research suggests that they might still be harmful to the environment. If the goal of adopting RESs is to protect the environment, treating them improperly could have the reverse effect. Numerous study papers on the detrimental environmental effects of a few particular RESs have been published in the literature [2]. However, there is a dearth of research that examines all RESs and illustrates how they might affect the environment. This study uses a SWOT analysis to show the negative environmental effects of all RESs and offers some suggestions for mitigating these effects. With the advent of the industrial revolution, greenhouse gases began to accumulate in the atmosphere. During the past century, greenhouse gas emissions have caused the world's temperature to rise [3]. There has been a steady increase in the temperature of Earth over the past few decades. In addition to using fossil fuels extensively, global warming is caused by the burning of these fuels. As a result of the use of fossil fuels, some power facilities emit greenhouse gases into the atmosphere, such as carbon dioxide (CO_2). Approximately 35% of greenhouse gases are released by current power plants [4]. The emissions of NOx and SO_2 from coal-fired power stations in China in 2015 were over 42% and 38%, respectively. Nearly 40% of all greenhouse gases are produced by coal-fired power plants [5]. These gases trap heat in the atmosphere, which causes Earth's temperature to rise. Global warming will contribute to the decline of our world's habitability if it continues at the current pace. As a result of rising temperatures, glacier ice melts, causing sea levels to rise. In many arid regions, there will be catastrophic droughts and conflagrations, and many islands and parts of many countries will drown. In order to meet the Paris Agreement's 2-degree warming limit, the electricity industry must decarbonize rapidly [4,6]. In addition, alternative energy sources are becoming more prevalent. Investments in renewable as well as sustainable energy will need to total USD3.5 trillion annually by the year 2050 [7]. Fossil-fuel-powered power plants emit half as much CO_2 as natural-gas-powered ones. Until renewable energy sources become more trustworthy and durable, natural gas could serve as a bridge fuel [8]. Access to affordable, clean energy ranks seventh on the UN's list of seventeen sustainable development objectives. It is believed that RESs are emission-free and readily available in the natural environment. With regard to the amount of electricity generated by various renewable energy sources [9], there is no doubt that hydropower ranks highest among all RESs. Solar photovoltaicand wind power each contribute to one quarter of the overall share. Over 6% of RESs come from geothermal, concentrated solar thermal, ocean, and biopower combined. While ocean power has the potential to contribute more to this outcome than any other renewable energy source, it only contributes 0.02%. All over the world, renewable energy sources are being used to produce power [10]. African and Middle Eastern countries have shares of less than 20%, while many European and South American nations, as well as Canada, have shares of over 60%. A majority of the population is divided between the United States, China, Mexico, Russia, Australia, and other countries. In order to protect the environment, a number of countries are adamant about cutting back on their use of fossil fuels and introducing RESs. By 2030, the European Union hopes to lead the world in the use of renewable energy [11]. In fact, tidal energy alone is capable of providing about 28% of all of the energy needed by the UK [12–15].

The literature review is discussed in Section 2 of this study. The methodology is presented in Section 3. The application of the model is discussed in Section 4. The results and discussion are presented in Section 5. The discussion of the study is presented in Section 6. In Section 7, a conclusion is presented. Table 1 represents the Short Form/Acronym/Abbreviation of this study.

Table 1. Common terms.

Full Form	**Short Form/Acronym/Abbreviation**
Analytic Hierarchy Process	AHP
Analytic Hierarchy Process Technique for Order Preference by Similarities to Ideal Solution-I	AHP-TOPSIS-I
Augmented Mean Group	AMG
BestWorst Method	BWM
BestWorst Method Technique for Order Preference by Similarities to Ideal Solution-I	BWM-TOPSIS-I
Carbon Dioxide	CO_2
Common Correlated Effects Mean Group	CCEMG
Consistency Ratio	CR
Consistency Index	CI
Data Envelopment Analysis	DEA
Decision Making Trial And Evaluation Laboratory	DEMATEL
Decision Making Trial And Evaluation Laboratory Technique For Order Preference By Similarities To Ideal Solution-I	DEMATEL-TOPSIS-i
Distributed Generation	DG
Full Consistency Method	FUCOM
Full Consistency Method Technique for Order Preference by Similarities to Ideal Solution-I	FUCOM-TOPSIS-I
Maintenance and Operations Cost	M&O Cost
Microgrid	MG
Multiple-Criteria Decision Analysis	MCDA
Multi-Criteria Decision Making	MCDM
Priority Value	PV
Priority Values	PVs
Preference Ranking for Organization Method for Enrichment Evaluation	PROMETHEE
Renewable Energy Source	RES
Simple Additive Weighting	SAW
Simple Multi-Attribute Rating technique	SMART
Strength, Weakness, Opportunity, and Threat	SWOT
Sustainable Development Goal Seven	SDG-7
Technique for Order Preference by Similarities to Ideal Solution	TOPSIS
Technique for Order Preference by Similarities to Ideal Solution-I	TOPSIS-I
Vlse Kriterijumska Optimizacija Kompromisno Resenje	VIKOR
Weighted Sum Model	WSM
Weighted Sum Model Technique For Order Preference by Similarities to Ideal Solution-I	WSM-TOPSIS-I

2. Literature Review

Various renewable energy sources are being studied at the state level in line with SDG-7 (Sustainable Development Target 7). Clean, accessible, and contemporary energy systems are an important component of the seventh Sustainable Development Goal. A further aspect of this study is that it uses data from specific Asian nations, which is intended to increase the impact of sustainable energy use. With annual panel data collection and the AMG and CCEMG methodologies, this study analyzes data using these methodologies [16].

Using a renewable green hydrogen source created from geothermal, wind, biomass, and solar energy, Zhao et al. (2022) studied workable solutions to Pakistan's energy problems. Based on four primary criteria, economic viability, including social acceptance, environmental viability, and commercial viability, the use of MCDM and fuzzy-analytical hierarchical approaches in this context was studied. The development of hydrogen energy via renewable sources was examined using DEA [17].

By controlling for other macroeconomic variables, Steve et al. (2022) examines the relationship between renewable energy usage and economic growth in different parts of Sub-Saharan Africa between 1990 and 2018. Besides Dumitrescu–Hurlin Granger causality testing, the CCEMG takes into account cross-sectional dependence as well as cross-country heterogeneity. CCEMG's results are consistent regardless of the location of the sample, namely East, West, or Central Africa. The growth hypothesis is consistent with the Granger causality for both East and West Africa, while the feedback theory is only consistent with Central Africa [18].

Using the CCEMG, AMG, and Dumitrescu–Hurlin causality procedures, Sadiq et al. (2023) developed a model for estimating cross-sectional dependence and slope heterogeneity. In empirical studies, nuclear energy and technological advancement reduced carbon emissions and led to a reduction in environmental costs. By causing atmospheric carbon emissions to increase, globalization, however, raises environmental costs. Moreover, renewable energy, nuclear energy, and carbon emissions are bidirectionally linked. Therefore, the countries that consume the most nuclear energy must maximize nuclear energy efficiency in order to reduce environmental costs and contribute to a low-carbon economy. In addition, this viewpoint was designed to strengthen the justifications of decisionmakers [19].

Dashtaki (2023) proposes an optimization strategy to minimize overall cost and operate a grid-connected MG as efficiently as possible. This study also takes into account DG systems that use renewable energy sources, such as solar and wind power. Through the power exchange between the MG and the distribution system, system equilibrium is established between total electricity generation and essential consumption. The optimization problem's objectives include lowering total power losses in the distribution system, improving the voltage profile, and lowering operational and planning expenses for the MG system [20].

Fakher et al. (2023) used the N-shaped environmental Kuznets curve framework to determine how non-renewable and renewable energy use affected environmental sustainability. Six variables were employed in this study rather than one to reflect environmental quality. Environmental deterioration can be measured using pressures on ecological footprints, nature, adjusted net savings, and ecological vulnerability. On the other hand, environmental sustainability and green performance can be used as indicators of environmental quality [21].

The various energy harvesting techniques were reviewed and case studies were conducted by Arrafi et al. (2023). In terms of energy generation, viability, and maintenance, solar energy collection is now the most useful in the transportation infrastructure. There is a much higher level of progress in solar energy harvesting research than in mechanical or thermal energy harvesting. With greater research and technological advancements, mechanical energy harvesting has the potential to overtake other energy collection techniques in transportation infrastructure. Automobiles place a significant mechanical load on transportation infrastructure as a result of their size and weight [22].

2.1. Research Gap

The sustainability of diverse sectors is not discussed in the material previously given. Energy is a key component of the Sustainable Development Goals, from expanding access to power to improving clean cooking fuels. In addition, they emphasize the significance of cutting back on unnecessary energy subsidies and air pollution, which prematurely kill millions of people every year. Making inexpensive, dependable, sustainable, and modern energy available to everyone by the end of the next decade is one of SDG-7's goals. Thus, the following research question arises: which sector(s) of sustainable energy is/are the most appropriate?

In some studies, MCDM techniques were used. As it advances society's use of sustainable energy sources, the Electricity Union is committed to providing many clients with reliable, cheap energy. A number of criteria were developed to assess whether the twenty-three EU member states are achieving the Energy Union's goals. For ranking the EU nations based on their sustainable energy development, this study used the SWARA-TOPSIS framework based on Pythagorean fuzzy sets [23].

Examine the best renewable energy options for Turkey's sustainable growth using the IF-TOPSIS method. According to the criteria established and the sustainable growth limitation, obtain Turkey's preferences for renewable energy investments optimally. If there are a number of criteria and possibilities available, complex information is available, and decisionmakers are hesitant, this approach produces the best results [24].

Coalenergy cities are increasingly exhibiting contradictions, posing a significant drawback to optimizing and upgrading these cities. Departments at all levels are responsible for taking measures to improve and protect coal-dependent cities and supporting their economic transformation so that they can expand and develop sustainably. This study's analysis of coalenergy cities' economic transformation and sustainable expansion has been incorporated into the enlarged TOPSIS economic transformation evaluation model. TOPSIS is based on the recommended entropy weight [25].

The Indonesian fashion sector has significantly increased its waste and emissions due to population growth and economic growth. This problem can be solved by implementing a sustainable circular economy in order to achieve zero waste and sustainable development. Early studies lack a precise interrelationship model to guide behavior toward a sustainable circular economy. In order to address these issues, this study suggests combining exploratory factor analysis, fuzzy synthetic methods, and decision-making trials and evaluations in laboratories [26].

A process industry's psychosocial safety climate and safety climate influence employee performance. Data were collected from operators and supervisors in the control room, and MCDM techniques were applied to analyze them. Using the entropy technique, elements affecting the safety climate and the psychosocial safety climate were prioritized. To rate the options, TOPSIS was also used [27].

Recently, TOPSIS-based ranking methods have been used in some studies. Hwang and Yoon developed TOPSIS in 1981 [28].However, TOPSIS has a number of disadvantages. According to TOPSIS, the best alternatives should have the shortest distance and maximum distance [29]. In TOPSIS, the shortest distance is measured by the Euclidean distance [30,31]. The Euclidean metric does not always give the shortest distance between two points, which is one of the biggest disadvantages of TOPSIS. The shortest distance is always better calculated by the supreme metric than by the Euclidean distance in any dimensional problem. Majumder proposed the TOPSIS-I technique in 2020 to overcome these drawbacks [30]. Majumder used supremum metrics instead of Euclidean metrics in TOPSIS-I [30].

2.2. Objectives of the Study

This study aims for the following:

- To determine which sectors of the energy sector are most sustainable. This paper proposes an MCDM model for analyzing energy sector sustainability. According to the proposed model, the most environmentally friendly energy sector or sectors are selected. Literature reviews, surveys of experts, and reports have all been used to develop this list.

- In order to identify the most significant alternatives, BWM-TOPSIS-I, a hybrid MCDM technique, is suggested.
- In order to determine the weights or priority values (PVs) of a set of criteria, BWM is used.
- To determine the ranking of alternatives, TOPSIS-I is used in conjunction with BWM's PV determination.

The TOPSIS technique assumes that the shortest and longest distances should characterize the best options [29]. According to TOPSIS, the Euclidean distance has the shortest measurement [28]. In spite of this, Euclidean metrics do not provide the shortest distance between two points. The shortest distance is consistently determined by the maximum metric rather than the Euclidean distance in all dimensional situations. This new approach is proposed by Majumder and Saha [30] and the name of this approach is TOPSIS-I [31]. In the TOPSIS-I technique, the criteria weights are determined by using AHP techniques. The MCDM technique BWM was introduced in 2015 [32]. By identifying inconsistencies, decisionmakers can determine whether their most recent decisions were appropriate and whether their opinions are consistent [33]. Simple, accurate, and redundant information are some of the benefits of BWM. Although, AHP possesses numerous demerits, such as the redundant pairwise comparisons which do not allow for consistency. It is believed that BWM overcomes the difficulties of AHP. BWM will very soon gain the same level of popularity as the AHP, since it has fewer paired comparisons and a higher consistency level in the pairwise comparison matrix. In contrast to AHP, BWM merely conducts reference comparisons, necessitating just the quantification of the value of the best criterion in relation to all other criteria and the relevance of all criteria in relation to the worst criterion. As a result, when compared to AHP, BWM considerably improves the problem's overall consistency. Instead of using the AHP approach, the BWM approach is used in this study to establish the criteria weights. A consistent approach to decision making based on several factors is the main advantage of TOPSIS-I. Fundamental benefits of the TOPSIS-I technique areits simplicity, rationality, processing efficiency, and ability to quantify the relative performance of alternative options in a straightforward mathematical form. As one of the most widely used approaches in discrete MCDA research (including bipolar, VIKOR, PROMETHEE, SAW, and SMART), TOPSIS-I was selected. Aspects of the suggested paradigm have been covered by the objectivity and adaptability of the methodologies. TOPSIS-I was used in this study because it is a more reliable and consistent regression model than current regression models.

2.3. Novelty of the Study

In the present investigation, the following novelties are presented:

- To determine the ranking of alternatives, this study proposes hybrid decision making.
- A three-step complex decision-making problem based on the sustainability of RESs is solved by a hybrid approach suggested here.

3. Methodology

New hybrid techniques, namely BWM-TOPSIS-I, consist of two existing methods, namely BWM and TOPSIS-I. BWM determines the weights of the criteria, and TOPSIS-I determines the ranking of the alternatives. The proposed methodology is shown in Figure 1.

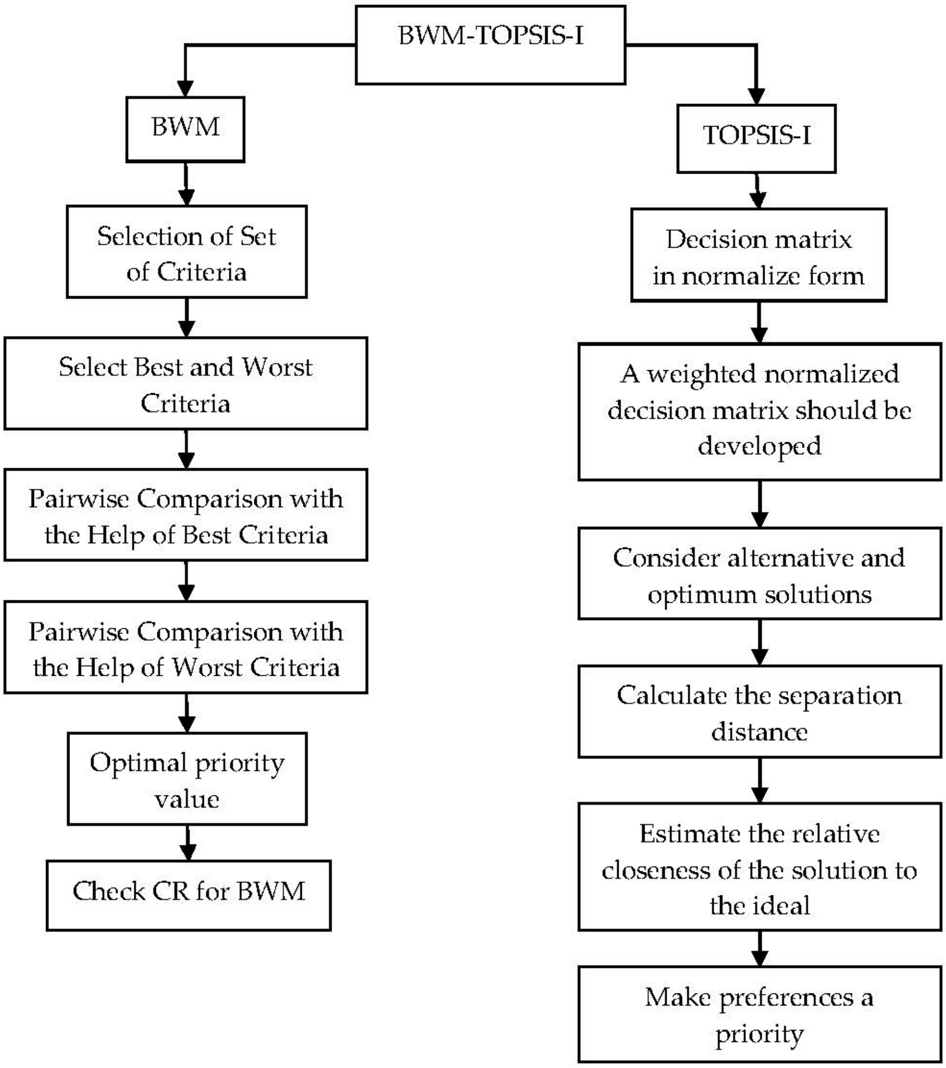

Figure 1. Flowchart of the proposed method.

3.1. BWM

This section describes how to compute the PV of each section's criteria using BWM stages.

Step I: Selection of set of criteria: First, select the set of decision criteria $X = \{x_1, x_2, \ldots, x_s\}$, where x_l denotes the lth criteria.

Step II: Establish which criteria are the most important and the least important: Choose the criteria that are of the greatest relevance (the best) and importance (the worst) among group X. Surveys were conducted to determine the best and worst criteria (such as expert surveys, literature surveys, stakeholder surveys, etc.).

Step III: Pairwise comparison with the help of best criteria: Using Satty's scale, evaluate pairwise comparisons of all criteria with the help of best criteria denoted by the set X_B.

$$X_B = \{x_{B1}, x_{B2}, \ldots, x_{Bs}\}$$

where x_{Bl} takes the values from Satty's scale and lth reflects the pairwise comparison represented by x_{Bl} criteria with the help of best criteria x_B, as well as $x_{BB} = 1$.

Step IV: Analyze the worst criteria by pairwise comparison using all criteria: Using Satty's scale, evaluate pairwise comparisons of all criteria over worst criteria denoted by the set X_W.

$$X_W = \{x_{1W}, x_{2W}, \ldots, x_{sW}\}$$

where x_{lw} takes the values from Satty's scale and x_{lB} represents the pairwise comparison of lth criteria over the worst criteria x_W and $x_{WW} = 1$.

Step V: Optimal priority value (PV): For each criterion in this section, determine the best PV. Let $p_1, p_2, \ldots, p_s$ be the decision PV of the criteria $x_1,\ x_2, \ldots, x_s$, respectively. Let p_B and p_W be the PVs of x_B, as well as x_W, respectively. It is conceivable for all l to satisfy Equations (1) and (2) for optimal PV ratios $\frac{p_B}{p_l}$ and $\frac{p_l}{p_W}(l = 1\ (1)\ s)$ if the minimum and maximum gaps of $\left|\frac{p_B}{p_l} - x_{Bl}\right|$ and $\left|\frac{p_l}{p_W} - x_{lW}\right|$, and $\forall l = 1\ (1)\ s$ are evaluated. PVs must not be negative and sum to zero for the following optimization problem:

$$\begin{gathered} \min\max_{l}\left\{\left|\frac{p_B}{p_l} - x_{Bl}\right|, \left|\frac{p_l}{p_W} - x_{lW}\right|\right\} \\ Subject\ to \sum_{l=1}^{s} p_l = 1 \\ p_l \geq 0\ \forall l = 1\ (1)\ s \end{gathered} \tag{1}$$

This transforms the optimization issue (1) into a non-linear one. As a result of the non-linear transformation of Equation (2), the formed form looks as follows:

$$\begin{gathered} \min\theta \\ Subject\ to \left|\frac{p_B}{p_l} - x_{Bl}\right| \leq \theta,\ \forall l = 1\ (1)\ s \\ \left|\frac{p_l}{p_W} - x_{lW}\right| \leq \theta,\ \forall l = 1\ (1)\ s \\ \sum_{l=1}^{s} p_l = 1 \\ p_l \geq 0\ \forall l = 1\ (1)\ s \end{gathered} \tag{2}$$

Step VI: Check CR for BWM: When examining the consistency of pairwise comparisons, the CR value is of primary importance. The matrix value $x_{Bl} \times x_{lW} - x_{BW} = 0$ is consistent for pairwise comparisons in BWM. It is contradictory if $x_{Bl} \times x_{lW} - x_{BW} > 0\ or < 0$ is used in the pairwise comparison matrix. The maximum inequality will be produced, which is θ, when x_{BW} is equal to both x_{Bl} and x_{lW}. As the relationship $\left(\frac{p_B}{p_l}\right) \times \left(\frac{p_l}{p_W}\right) - \left(\frac{p_B}{p_W}\right) = 0$ contains the largest disparity, Equation (3) can be derived as follows:

$$(x_{Bl} - \theta) \times (x_{lW} - \theta) - (x_{BW} - \theta) = 0 \tag{3}$$

For the maximum inconsistency, $x_{Bl} = x_{lW} = x_{BW}$; thus, the equation transforms into

$$\theta^2 - (1 + 2x_{BW})\theta + \left(x_{BW}^2 - x_{BW}\right) = 0 \tag{4}$$

Put $x_{BW} = 1,\ 2,\ 3,\ \ldots, 9$ into Equation (4), solve that equation, and take the maximum root (θ^*) of Equation (4) taken as a consistency index (CI) value for each θ. All the CI values are represented in Table 2.

With the help of CI and θ^*, determine the value of CR which is represented by Equation (5).

$$CR = \frac{\theta^*}{CI} \tag{5}$$

3.2. TOPSIS-I

In this section, we describe the TOPSIS-Iprocesses that can be used to determine the rank of the alternative.

Table 2. Consistency index.

x_{BW}	$CI(\theta^*)$
1	0.00
2	0.44
3	1.00
4	1.63
5	2.30
6	3.00
7	3.73
8	4.47
9	5.23

Step I: Normalize the decision matrix: First, consider a set of alternatives whose cardinality is r. Then, calculate all entries of the decision matrix. A normalized decision matrix is $D = [\beta_{kl}]_{r\times s}$, and each entry is calculated with Equation (6).

$$\beta_{kl} = \frac{\sigma_{kl}}{\sqrt{\sum_{k=1}^{r} \sigma_{kl}^2}}, \ \forall k = 1(1)\ r \text{ and } \forall l = 1(1)\ s \tag{6}$$

Step II: A weighted normalized decision matrix should be developed: In the next step, evaluate the weighted decision matrix in normalized form. All of the entries' μ_{kl} of weighted normalized decision matrix aredetermined by Equation (7).

$$\mu_{kl} = p_l \times \beta_{kl}, \ \forall k = 1(1)\ r \text{ and } \forall l = 1(1)\ s \tag{7}$$

where p_l is the PV of the lth criterion determined from the equation solving Equation (2), and

$$\sum_{l=1}^{s} p_l = 1$$

Step III: Consider alternative and optimum solutions: using Equation (7), evaluate two ideal solutions, namely positive and negativeideal solutions.

$$\varphi^+ = \{\mu_1^+, \mu_2^+, \mu_3^+, \ldots, \mu_r^+\} = \{(\max_k \mu_{kl} | l \in \mathsf{C}_b),\ (\min_k \mu_{kl} | l \in \mathsf{C}_c)\}$$

$$\varphi^- = \{\mu_1^-, \mu_2^-, \mu_3^-, \ldots, \mu_r^-\} = \{(\max_k \mu_{kl} | l \in \mathsf{C}_b),\ (\min_k \mu_{kl} | l \in \mathsf{C}_c)\}$$

where the benefit and cost criteria are represented by C_b and C_c, respectively.

Step IV: Calculate the separation distance: Apply the r dimensional supremum distance for measure of separation. The separations of each alternatives and negative from the ideal solutions are calculated by the Formulas (8) and (9), respectively.

$$\vartheta_k^+ = \max\{|\mu_{kl} - v_l^+| : l = 1, 2, \ldots, s\}, \forall k = 1(1)\ r \tag{8}$$

$$\vartheta_k^- = \sqrt{\sum_{l=1}^{s} (\mu_{kl} - v_l^-)^2}, \forall k = 1\ (1)\ r \tag{9}$$

Step V: Estimate the relative closeness of the solution to the ideal: In this step, evaluate the ideal solution of relative closeness. With the help of ϑ_k^- $(k = 1(1)\ r)$, calculate the closeness of the alternative A_k $(k = 1(1)\ r)$ using Equation (10).

$$RC_k^* = \frac{\vartheta_k^-}{\vartheta_k^- + \vartheta_k^+}, \forall k = 1(1)\ r \tag{10}$$

Step VI: Make preferences a priority: Finally, determine the rank of order of each alternative. From Equation (10), it is clear that the RC_k^* value belongs to (0, 1). Alarger index value indicates beingcloser to the ideal solution for alternatives.

4. Application of the Model

The goal of the current study is to determine which energy sector practices are the most sustainable. In this study, the sustainability of the energy sector wasexamined using a hybrid MCDM method, namely BWM-TOPSIS-I. Although spherical fuzzy sets (SFSs), picture fuzzy sets (PFSs), and Fermateanfuzzy sets (FFSs) are many novel extensions of fuzzy sets, no fuzzy technique wasapplied in this study asno linguistic term wasused in the decision-making problem. The total mechanism wasbuilt on the score value which wascollected from anexpert on the related topic. A contract with specialists is the first step in providing alternatives. Next, send sustainability-related considerations. Based on their judgment and an assessment of the literature review, choose your criteria and alternatives. Hire specialists who can recommend specifications for sending an opinion about the rank of variables using a five-point scale for TOPSIS-I and a nine-point scale for BWM. The judgments of the three experts served as the basis for the final rankings. There are several issues with the AHP that need to be fixed by the proposed model, including the excessive number of comparisons between criterion pairs. Using only 2n − 3 comparisons between criterion pairs, the proposed model can determine the optimal weight coefficient values. Through a limited number of pairwise comparisons, inconsistencies in the criterion comparisons are eliminated. The results are more consistent due to the transitivity relations being less weakened, which further enhances the ability to produce more reliable results (in comparison to the AHP). Criteria, sub-criteria, and alternatives are outlined in Table 3.

Table 3. A discussion of criteria, sub-criteria, and alternatives.

Criteria	
Technical [34]	As a result of this advancement, several technological innovations that can enhance renewable energy sources have been developed. For example, artificial-intelligence-controlled robots are used to monitor and improve the efficiency of hydropower plants and reduce maintenance costs. A hybrid hydropower and battery system is being developed to enhance grid services, and a "hyperloop for fish" is being developed to safely transport fish over dams.
Economic [35]	Electricity production costs are reduced when fuel costs are reduced. Additionally, electricity does not change in price as a result of changes in fuel prices, unlike natural gas or coal. There might be a decrease in energy prices over time as a result of this.
Environmental [36]	RESs, such as wind and hydropower, as well as solar, are considered sustainable because they have little negative impact on the environment and are widely available.
Sub-Criteria	
Efficiency [37]	The energy efficiency of an economy is influenced by a variety of factors. This reduces carbon emissions, which in turn reduces climate change. Additionally, it creates jobs that lower poverty and improve sustainable livelihoods.
Life Time [38]	There are many environmental issues directly related to the production and consumption of energy, including air pollution, water pollution, climate change, waste disposal, and thermal pollution. Fossil fuel combustion is the primary cause of urban air pollution.
Plant Factor [39]	Water and oxygen are created by plants, while CO_2 is converted into chemical energy in the form of glucose. As our climate changes, plants provide energy, trap CO_2, and maintain breathable air quality in a world threatened by climate change.
Per Unit Cost [40]	The most adverse effect on energy sustainability was caused by an increase in coal prices, whereas the least adverse effect was caused by an increase in solar energy prices. Gas prices are unaffected by an increase, but gasoline prices are positively affected by an increase.
Fuel Cost [41]	When fossil fuels are burned, massive amounts of carbon dioxide are released into the atmosphere. In our atmosphere, greenhouse gases trap heat, causing global warming.

Table 3. *Cont.*

O&M Cost [42]	According to the Paris Agreement, significant investments are needed in solar photovoltaics and wind turbines. In order to describe workable transition pathways and identify necessary support measures, it is crucial to understand their cost reduction dynamics. In previous studies, the majority of the focus was on developing and installing equipment.
CO_2 Emissions [43]	There is a bidirectional causal link between energy use and CO_2 emissions. Energy use results in CO_2 emissions in the short term, suggesting that higher energy use could result in higher CO_2 emissions in the long run.
Land Requirement [38]	A sustainable energy system requires a balance between economic growth, environmental protection, and energy security. A key component of this is energy systems, which are based on the three key principles of energy security, social equality, and environmental protection.
NOx Emissions [44]	A person's respiratory system can be adversely affected by increased nitrogen dioxide levels, making them more vulnerable to respiratory infections and asthma. When nitrogen dioxide concentrations are high, chronic lung disease can develop.
Alternatives	
Hydro [39]	As part of the Sustainable Development Goals, renewables are supposed to make up more of the world's energy mix by 2030. There are major implications associated with the growth of hydropower on an international scale.
Gas [45]	Despite not being as clean as wind or solar electricity, natural gas is the cleanest fossil fuel. The transition to a greener future is widely believed to be aided by natural gas. Natural gas is primarily generated domestically in the United States, according to the Energy Information Administration.
Coal [46]	It is not possible to use fossil fuels such ascoal, natural gas, and others in a safe or sustainable manner. It is not recommended that they be applied. Natural gas, coal, and oil are fossil fuels that were formed by the decay of living organisms over time. Over twothirds of our electricity is generated by them in the US, so they provide most of our energy needs.
Solar [39]	Solar and wind power are examples of renewable energy sources that continuously and organically replenish themselves. Renewable energy is also known as sustainable energy.
Diesel [47]	Contributes to climate action and environmental stewardship by reducing greenhouse gas emissions, shrinking our water footprint, and increasing reuse and recycling rates.

Sections 4.1–4.3 describe the application of BWM, the application of TOPSIS-I, and the validation of the model. As shown in Figure 2, the decision-making problem has a hierarchical structure.

4.1. Application of BWM

BWM was applied to calculate the PV of the criteria as well as the sub-criteria in this study.

4.1.1. Application of BWM to Criteria

As a starting point, determine which criteria are the best and worst based on a consensus of experts. Experts rate technical factors as the best, followed by economic factors. Using the criteria listed in Table 4 below, we will compare each criterion pairbypair. Similarly to the previous pairwise comparison, a worstcriterion comparisonwascarried out using each of the criteria, as indicated in Table 5. As soon as the pairwise comparison matrix has beenconstructed, Equation (11) represents the mathematical formulation of the decision-making optimization issue.

$$
\begin{gathered}
\min\theta \\
ubjectto\left|\frac{p_1}{p_2}-6\right| \leq \theta \\
\left|\frac{p_1}{p_3}-3\right| \leq \theta \\
\left|\frac{p_3}{p_2}-4\right| \leq \theta \\
\sum_{l=1}^{3} p_l = 1 \\
p_l \geq 0 \; \forall l = 1\,(1)\,3
\end{gathered} \tag{11}
$$

where p_1, p_2, and p_3 represent the PV of thetechnical, economic, and environmental criteria, respectively.

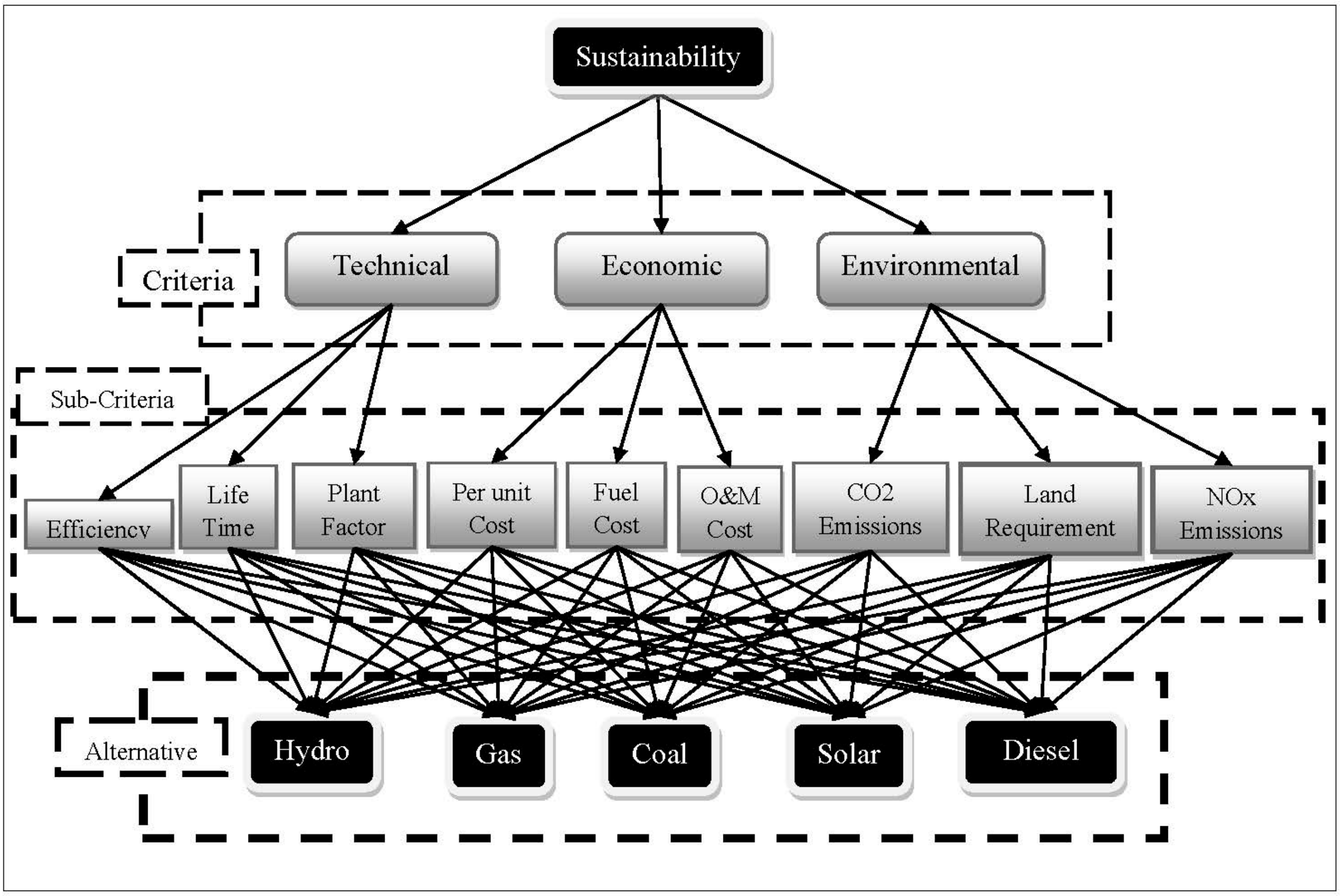

Figure 2. Hierarchical decisionmaking is involved.

Table 4. Comparison of each criterion in pairs in relation to the best criterion.

Best Compared to Others	Technical	Economic	Environmental
Technical	1	6	3

Table 5. Pairwise worst criterion for each set of criteria.

Others Compared to the Worst	Economic
Technical	6
Economic	1
Environmental	4

4.1.2. Application of BWM to Sub-Criteria

Using the same approach as the main criteria, determine the weights of the sub-criteria. Experts agree that efficiency is the most important sub-criterion, while M&O costs are the least important. Each pair of sub-criteria is then compared using the best sub-criteria in Table 6. Similarly to a pairwise comparison, Table 7 shows the worst sub-criterion comparison based on each sub-criterion. In order to describe this mathematical formulation, create an equation that closely resembles (11) after constructing the pairwise comparison matrix.

Table 6. A pair-wise comparison of each sub-criterion with its best sub-criterion.

BestComparedto Others	Efficiency	Life Time	Plant Factor	Per Unit Cost	Fuel Cost	O&M Cost	CO_2 Emissions	Land Requirement	NOx Emissions
Efficiency	1	3	2	4	5	9	8	7	6

Table 7. Pairwise analysis of the worst sub-criteria for each set of sub-criteria.

Others Compared to the Worst	O&M Cost
Efficiency	9
Life Time	3
Plant Factor	2
Per Unit Cost	4
Fuel Cost	5
O&M Cost	9
CO_2 Emissions	8
Land Requirement	7
NOx Emissions	6

4.2. Deployment of TOPSIS-I

The first step is to determine the PVs of each of TOPSIS I's criteria and sub-criteria using any MCDM method. BWM wasused in this work to calculate the PV for each criterion and sub-criterion. TOPSIS-I wasused to rank alternatives based on the PVs of the criteria and sub-criteria. In this study, the relative scores were determined using five-point measures [28]. To determine each parameter's relative score in relation to each criterion, a literature review and expert survey were used. A five-point scale is used in Table 8 to display the relative scores.

Table 8. The criteria are ranked in a table of possible options.

Alternative	Efficiency	Life Time	Plant Factor	Per Unit Cost	Fuel Cost	O&M Cost	CO_2 Emissions	Land Requirement	NOx Emissions
Gas	5	3	5	4	3	5	4	3	5
Solar	4	4	4	3	4	5	4	4	5
Diesel	2	4	5	2	3	4	3	3	4
Hydro	3	2	3	3	2	3	5	2	3
Coal	1	3	2	4	3	3	1	3	4

4.3. ModelValidation

A comparative study as well as a sensitivity analysis are included in this section to help to validate our hypothesis. A description of the entire subdivision can be found in Sections 4.3.1 and 4.3.2.

4.3.1. Comparative Study

In the present study, the results of the proposed method were compared with those of some sophisticated techniques, such as AHP [28], TOPSIS [48], AHP-TOPSIS-I [31], and BWM-TOPSIS [49].

4.3.2. Scenario Analysis

The sensitivity of the MCDM technique can be assessed by adjusting the amount of secondary criteria. There are some key alternative values that remain unchanged. Therefore, if the rank wasto change in any way, the technique would be considered sensitive, and vice versa. The rank relative sensitivity analysis of Hamby (1994) has been put forward as one of the types of sensitivity analysis [50].

5. Results and Discussion

The results and discussion are divided into four sub-sections: Sections 5.1–5.4.

5.1. Results and Discussion from BWM

Using the BWM approach, PVs are used to calculate the relative relevance for the criteria. The best PVs can be determined by solving Equation (11) for the three criteria (technical, economic, and environmental). These are $p_1^* = 0.655, p_2^* = 0.091, p_3^* = 0.255$, and $\theta = 0.10$. For the CR, as $x_{B1} = 6$, the CI for this problem is 3.00, and the CR is 0.109/3 = 0.0263, which implies verygoodconsistency.BWM can also be used to calculate PVs for the sub-criteria. In Table 9, the PV for each criterion and sub-criterion is given.

Table 9. PV of criteria as well as sub-criteria.

Criteria	PV	Sub-Criteria	PV
Technical	0.655	Efficiency	0.215
Economic	0.091	Life Time	0.143
Environmental	0.255	Plant Factor	0.215
		Per Unit Cost	0.107
		Fuel Cost	0.086
		O&M Cost	0.048
$\theta = 0.109$ CI = 3.00 CR = 0.109/3 = 0.0263		CO_2 Emissions	0.054
		Land Requirement	0.061
		NOx Emissions	0.072
		$\theta = 0.215$ CI = 5.23 CR = 0.215/5.23 = 0.0411	

5.2. Results and Discussion from TOPSIS-I

The rank of options wasestablished using the TOPSIS-I approach.Criteria weights usedin the TOPSIS-I method were from the BWM method. Table 10 represents the RC_k^* value of alternatives. According to the results, gas is the most important alternative.

5.3. Comparative Study

The analysis should utilize a few existing methodologies as well as the new method, BWM-TOPSIS-I, suggested by this study. A summary of the values and the ranking of the provided alternatives can be found in Table 11. The proposed strategy performs better than the current methods, as can be seen in Table 9. When looking at the findings presented in this table, we can see that the best option found using the suggested strategy is consistent with all other methods already in use. The BWM approach is efficient for criterion selection, which is why this advanced approach may be well-versed. In addition, despite the fact that gas is the best alternative, the computational procedures for these approaches differ, as shown in this table.

Table 10. RC_k^* value of each alternative.

Alternatives	ϑ_k^+	ϑ_k^-	RC_k^*	Rank
Gas	0.358	0.859	0.706	1
Solar	0.358	0.644	0.643	2
Diesel	0.644	0.286	0.308	5
Hydro	0.429	0.429	0.5	3
Coal	0.859	0.429	0.333	4

Table 11. Study results of comparative analysis.

Alternative	Proposed Method		AHP-TOPSIS		AHP-TOPSIS-I		BWM-TOPSIS	
	RC_k^*	Rank	RC_k^*	Rank	RC_k^*	Rank	RC_k^*	Rank
Gas	0.706	1	0.692	1	0.701	1	0.728	1
Solar	0.643	2	0.631	2	0.652	2	0.643	2
Diesel	0.308	5	0.301	4	0.297	5	0.359	5
Hydro	0.5	3	0.433	3	0.511	3	0.47	3
Coal	0.333	4	0.292	5	0.312	4	0.381	4

5.4. Result from Sensitivity Testing

We carried out sensitivity analysis to find this kind of estimation. The results of the sensitivity analysis are shown in Figure 3. Five alternatives served as the input variables, while the index function served as the output (weighted sum of alternatives). Each input parameter's sensitivity was evaluated using its seinˆg2 value. According to the analysis, gas has a Swingˆ2 value of 36.40%. With a Swingˆ2 value of 30.20%, gas was determined to be the most sensitive parameter, and diesel was determined to be the second-most-sensitive parameter. The least sensitive characteristic, on the other hand, wasdiscovered to be coal, with a Swing2 value of 6.90%. According to the BWM-TOPSIS-I, this shows that "gas" is the parameter that is most sensitive to the PV, followed by the sustainability of the energy sector.

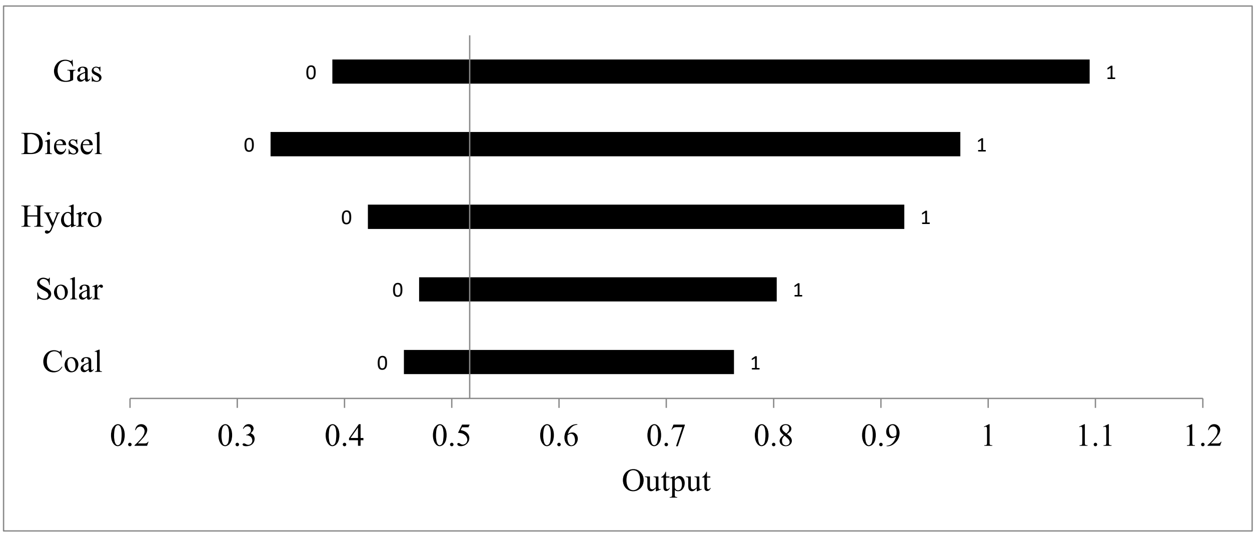

Figure 3. Result obtained from sensitivity analysis.

6. Discussion

The goal of the current study was to evaluate the more sustainable energy sector. For this, we developed a new model, namely BWM-TOPSIS-I. BWM was applied todetermine the weights of the criteria and sub-criteria. TOPSIS-I was applied todetermine the rank of alternatives. The proposed model was validated via comparative study and sensitivity analysis. According to the results, it was found that gas was amore sustainable energy form. This result has alsobeensupported by some existing studies [51,52].In addition, the results of the comparative study support the results of the proposed model. As a result of sensitivity analyses, gas wasalso found to be a more sensitive alternative. The strengths and weaknesses are discussed in Sections 6.1 and 6.2, respectively.

6.1. Advantages of the Presented Model

The new hybrid method has many advantages.

- As a result of the more reliable comparisons provided by BWM-TOPSIS-I, the results obtained through this method are quite trustworthy. BWM-TOPSIS-I also uses a consistency ratio to determine whether comparisons are credible (unlike MCDM approaches such as TOPSIS-I).
- In contrast to matrix-based MCDM methods such as AHP, BWM uses vectors, so fewer comparisons are required. BWM-TOPSIS-I, for example, requires only $2n - 3$ comparisons compared to TOPSIS-I's $n(n - 1)/2$ comparisons.

6.2. Limitations of the Presented Model

The new hybrid method has many limitations.

- It is not always the interval's center that represents the optimal weight coefficient. The interval's right or left end may have a more important value. Interval PVs are much lower than optimal priority coefficient values when results are more inconsistent.
- The method does not ensure that if the number of participants increases or decreases, the ranking will remain the same.

7. Conclusions

This study has given birth to hybrid decision making which can be made use of in order to determine the ranking of alternatives. Furthermore, this study has offered a hybrid approach which can solve a three-step complex decision-making problem based on the sustainability of RESs. Comparative study and sensitivity analysis validate the model. Gas is a more sustainable energy form, as found through this study. The optimal weight coefficient is not always represented by the center of the interval. The right or left possess values of more significance. Optimal priority coefficient values are higher than interval weight values. It is not ascertained by the method that the rankings remaining the same is proportional to the participants increasing or decreasing. In the feature, the study developed some hybrid MCDMs, namelyWSM-TOPSIS-I, DEMATEL-TOPSIS-I, and FUCOM-TOPSIS-I, etc. The feature also develops fuzzy TOPSIS-I. After that, the development of TOPSIS-I for spherical fuzzy sets (SFSs), picture fuzzy sets (PFSs), and Fermatean fuzzy sets (FFSs) occurs.

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