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IT2 Fuzzy-Based Multidimensional Evaluation of Coal Energy for Sustainable Economic Development

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Abstract: The aim of this study is to determine the impact of coal energy on the economic development of countries. For this purpose, similar studies in the literature have been examined and nine different criteria have been determined for three dimensions affecting the use of coal energy. In order to determine the most important factors, an analysis is performed with IT2 fuzzy DANP method. The most important contribution of this study to the literature is that a proposal can be made for the use of coal energy by considering both positive and negative opinions related to this energy. On the other hand, IT2 fuzzy DANP method has been taken into consideration in this study for the first-time regarding coal energy and it is believed that methodological originality has been achieved. It is identified that social factors have the most importance in the use of coal energy. In this context, environmental pollution, health problems and demographic factors resulting from the use of coal energy should be taken into consideration in the use of this energy. Thus, problems arising from the use of coal energy far outweigh the economic benefits of using this energy. Therefore, factors that may prevent air pollution, such as carbon capture technology, should be considered in the use of coal energy. In addition, the use of high-quality coal will contribute to the reduction of the problems caused with this energy. In addition, investing in renewable energy sources that do not have negative impacts on the environment is also important for the sustainability of future energy policies.

Keywords: coal energy; sustainable economic development; IT2 fuzzy DANP

1. Introduction

Coal is a mineral which consists of carbon, oxygen and hydrogen. For this reason, it is considered as one of the most important non-renewable energy sources. Coal is used in many different fields, but today it is mainly considered to obtain the most electrical energy. In addition, one of the purposes of coal is heating. Furthermore, coal is used as an important raw material in the iron and steel industry. As can be seen, coal has an important place in the daily life of people. On the other hand, it also plays an important role in increasing industrial investments. Therefore, it can make a significant contribution to the economic development of countries [1].

Not all countries have enough reserves of oil and gas. Hence, for the countries where coal reserves are available, it will be costly to meet the energy need by importing natural gas from other countries. In addition, since the payment to be made in natural gas will be in a foreign currency, the country will be exposed to exchange rate risks. In other words, if the country's local currency depreciates, the energy imported from abroad will become more expensive. In this context, the use of coal reserves within the country will help prevent such risks. In addition to this issue, unlike other energy sources, coal is stable. Therefore, coal is the easiest fuel to transport, store and use [2].

Nevertheless, coal energy use has some important disadvantages. The most prominent negative factor is related to the environmental damage caused by coal. First, carbon dioxide and carbon monoxide are emitted into the atmosphere as a result of coal usage, which causes air pollution [3]. As a result of this situation, there is a risk that people will suffer from respiratory diseases. For example, it is assumed that the use of coal increases the incidence of lung cancer. In addition to air pollution, the use of coal is also considered to pollute waters. The wastewater generated during the extraction of coal pollutes clean water and this situation threatens human health [4]. In addition to these issues, noise pollution is another important problem in the use of coal energy. Equipment used in the process of obtaining coal produces disturbing noise. This situation makes it very difficult for people to live in these regions. Furthermore, coal usage also causes solid pollution. In this scope, due to the use of coal, high amounts of sulfur will cause damage to the soil [5].

Thus, there are many negative consequences arising from the use of coal energy. Within this framework, the most important issue is the diseases caused by environmental pollution and their economic costs. As a result of coal use, both air and environmental pollution occurs. These impurities lead to very serious diseases such as cancer. Expenditures for the treatment of these diseases also constitute a heavy burden on the state budget. In other words, this view contradicts the claim that coal is advantageous because of its low cost [6]. Moreover, coal use is one of the most important reasons for the increase of atmospheric carbon dioxide levels. Since this condition disrupts the balance of the atmosphere, increases in the average temperature will occur. This situation gives rise to the problem of climate change. This in turn causes dangers such as droughts, floods and hurricanes. Therefore, climate changes are considered to threaten human health seriously, especially in recent years [7]. In addition, the use of coal energy also causes internal migration within the country. People who live near coal mines migrate to other locations in the country due to the negative effects of these mines. This situation leads to unbalanced population distribution in the country. On the other hand, workers working in coal mines may also suffer from psychological problems due to negative work conditions [8].

It is obvious that the use of coal energy has many positive and negative views. Therefore, it is vital to conduct a cost-benefit analysis of coal. According to some researchers, coal has an economic advantage because of its low cost. However, in some studies, expenditures for the treatment of diseases caused by coal energy eliminate this economic advantage. In addition, coal is a low-cost resource, and is particularly recommended for countries that do not have oil and gas reserves. On the other hand, some researchers have claimed that energy companies in countries with high air pollution will have difficulty in obtaining funds. The main reason for this is that environmental pollution is a consideration in the decision of international financial institutions to provide credit. When these different views are examined, it is understood that there is a need for a new analysis that deals with all these different aspects of the use of coal energy.

Another issue that stands out in this process is which method should be used in an analysis of the efficiency of coal energy. An analysis with a method that has not been validated will lead to erroneous results. Therefore, an effective method should be taken into consideration during the examination. Multi-criteria decision-making methods are important applications in this process. These methods are mainly accounted in determining which of the many different criteria is more important. Especially in the recent years, it has been seen in the literature that multi-criteria decision-making methods have been taken into consideration with fuzzy logic. The main advantage of the fuzzy logic approach is that it uses linguistic variables to solve the problem [9]. This helps us to achieve results more effectively in a complex environment. Considering the recent studies using fuzzy logic, it is seen that type 2 is considered in fuzzy logic. The main reason for this is to minimize the uncertainties encountered in the fuzzy logic process [10].

In this study, we try to determine the role of coal energy in the economic development of countries. In this context, firstly the literature is reviewed and factors affecting coal energy use are defined. In this context, nine different criteria are selected for three different dimensions. The selected dimensions and criteria include both social, economic and productivity issues. An analysis is performed with the IT2

DANP method in order to determine the most important ones among the mentioned dimensions and criteria. DANP approach is the combination of DEMATEL and ANP methods. These two methods mainly aim to calculate the significance values of different factors that affect the decision making process. With respect to DEMATEL, expert evaluations are converted into linguistic terms and an initial direct relation matrix is generated. Later, a normalization process is performed to make the data more meaningful. In the final process, the weights of different factors are identified. On the other hand, regarding the ANP approach, there is a binary comparison between the factors. In the next step, supermatrix and limit supermatrix are generated and finally, the factors can be weighted.

We believe this study contributes to the literature in many respects. There are different views on the use of coal energy. Therefore, the major novelty of this study is to provide a comparative analysis by considering the arguments of the studies with different views. In this way, it will be possible to make a proposal for the sustainable development of the use of coal in different countries. In other words, the results of this study can make a comparative evaluation for these two different views. Hence, appropriate strategies can be generated to make effective energy usage for the countries which can be very helpful for their future energy strategies. This situation also makes a contribution to sustainable energy policies. Another originality of the study is related to the method used in the analysis. The IT2 DANP approach has been taken into consideration in this study for the first-time regarding coal energy. Each of these two methods has many positive aspects compared to their counterparts. The ANP method eliminates the disadvantages of the hierarchical connection in AHP. In addition, the causality relationship between the factors can be determined by DEMATEL methodology. Therefore, it is possible to determine the most important criterion and to create an impact-relationship map between the criteria by means of this method.

There are five different sections in this study. The first part is the introductory part of the study. In this context, general information such as definition, advantages and disadvantages of coal energy will be given. On the other hand, in the second part of the study, similar studies in the literature will be analyzed. In addition, the IT2 DANP method used in the analysis of the study will be explained in the third part of the study. In addition, in this part, the results of the analysis are also explained. In the last section, policy recommendations developed by taking the analysis results into consideration will be given.

2. Literature Review

In the literature review, it is seen that the possible effects of coal use are discussed in many different studies. It is understood that most of these studies focus on the negative impacts of coal on the environment. These studies are summarized according to the type of the problem.

2.1. Environmental Pollution

One of the main issues is the carbon-containing gases released to the atmosphere as a result of the coal usage. This issue has been emphasized in many different studies. For example, Wang et al. [11] tried to evaluate the coal mining sector in China. In that study, it is stated that the use of coal causes serious air pollution in the country. Similarly, Oliveira et al. [12] conducted a study on Colombia and emphasized the importance of the same issue. Shapiro et al. [13] also focused on air pollution as a result of coal use in Korea. In the study in which the survey analysis was conducted, it is concluded that air pollution is an important problem. These authors also stressed that the health problems resulting from the use of coal will have negative economic repercussions on the country. Oskarsson and Bedi [14] and Wu et al. [15] conducted a study on India and China. In these studies, case analyses and literature reviews were performed. According to the results of these studies, it is identified that due to the negative impacts on the environment, legal restrictions should be put on the use of coal. In parallel with these studies, Li et al. [16] argued that China should pay attention to the use of renewable energy due to adverse environmental conditions. In addition, Feng et al. [17] conducted a case study and

proposed increasing taxes in China to reduce coal use. Munawer [18] presented a large literature review on the subject and stated that the use of coal adversely affects not only air but also fresh water.

2.2. Health Problems

On the other hand, some of the studies have emphasized the health problems caused by coal. As a result of the use of coal, mainly carbon dioxide and carbon monoxide gas are released into the atmosphere [19]. This situation creates serious pollution in the air and affects human health negatively. In addition, waste generated as a result of coal use adversely affects both the environment and fresh water [20]. Therefore, coal affects people's lives through these stages and in this case causes serious health problems. The use of coal is one of the most important reasons for the release of carbon-containing gases into the atmosphere. This situation also causes the climate change problem. The main reason for this is that as the amount of this gas released into the atmosphere increases, this will cause the air temperature to rise significantly. These rising air temperatures also lead to deterioration of the climate balance. As a result, natural problems such as droughts and storms occur. This is another issue that negatively affects people's health [7].

In this framework, Habib et al. [21] conducted a study on coal use in Bangladesh. In the study using Monte Carlo simulation analysis, it is identified that the use of coal causes serious health problems. This study mainly focuses on the negative impact of coal use on drinking water. Tong et al. [22] also examined the use of coal in China. These authors stressed that important health problems will occur as a result of coal being thrown into the trash. Xiao et al. [23] analyzed this issue for different country groups. Correlation analysis is considered in this study and it is found that those living near the coal mining areas are exposed to disease risks. On the other hand, Sun et al. [24] also examined the use of coal in China. In this study, it is concluded that air pollution caused by coal causes important health problems in the country. It is also determined that this situation could cause economic problems in the country in the long term.

Finkelman and Tian [25] reported that there is a relationship between coal use in China and lung cancer. On the other hand, Minichilli et al. [6] found that the use of coal causes serious long term health problems in Italy. Moreover, some studies have shown that the use of coal affects some demographic factors. For example, Chen and Chen [7] stated that there may be regional migration due to air pollution caused by coal use. Teng et al. [26] conducted a regression analysis on Chinese data and reached similar results. In addition to the mentioned studies, Huang et al. [27] conducted a survey analysis and stated that the workers working in the coal mine had psychological problems. Additionally, Cardooso [5] presented a review using the semi-structured interview technique for coal use in Columbia. According to the results of the interview, the negative factors created by coal reduce the quality of life of people.

2.3. Macroeconomic Problems

According to many different studies in the literature, it is underlined that coal, which has a significant share in the energy sector, has a significant impact on the macroeconomic conditions, such as employment, current account deficit and investments. It has been concluded that the use of coal energy positively affects employment in a significant part of the studies in the literature. For example, Aragon et al. [1] conducted a study on coal energy in the UK. In this study, the data between the period of 1975 and 2011 were examined by a panel data analysis method. It was determined that the use of coal energy increased male employment especially in the country. In parallel with this study, Bohlmann et al. [28] made a similar study for South Africa. In this study, using a simulation method, it has been determined that the use of coal energy increases in particular the semi-skilled labor force. Burke et al. [29] concluded that coal energy investments contributed to a 1% reduction in unemployment in Australia. Lobao et al. [30] and Patrizio et al. [31] examined US coal energy investments. In these studies, it is found that the use of coal energy reduces unemployment. In addition to the mentioned studies,

Marcos-Martinez et al. [32], Scholz et al. [33] and Winarno and Drebenstedt [34] are other important studies claiming that coal use contributes to the country's employment.

The impact of coal energy use on the country's current account balance has also been addressed by many researchers. In this context, most of the studies underlined that the use of coal energy reduces the current account deficit problem. Figueiredo et al. [35] conducted a study on the use of coal energy in Portugal. A simulation method was taken into consideration in the analysis process of the study. According to the results, if countries with coal reserves use these reserves to meet their energy needs, they will not have to import energy from other countries. In this case, the current account balances of these countries will not be adversely affected. In addition, Berk and Cin [36] conducted an analysis on coal energy in Turkey. In this analysis, it is stated that current account deficit problem will decrease if coal energy is used. Çıraklı [37] and Przychodzen and Przychodzen [38] achieved similar results in their studies. In addition to the mentioned studies, Mukherjee et al. [39] and Rokhim et al. [40] examined India and Indonesia in their studies and stated that it is possible to reduce the current account deficit problem if coal energy is used.

One of the important economic factors affecting the use of coal energy is investments. If there are coal reserves in the country, this will attract investors' attention. Investors wishing to benefit from the existing reserve facilities will increase their investments. In this case, it will contribute to the sustainable economic development of the country. Fan et al. [41] examined the coal market in China. In this study, which uses the tree pricing model, he stated that there may be a significant increase in investments in the country as a result of the use of coal energy. Jiang et al. [42] conducted an analysis with the help of ARIMA model for the same country. According to the results of the analysis, it is determined that the investments in the country will increase significantly in 2030 if coal energy is used. In addition, Matyjaszek et al. [43] and Yuan et al. [44] conducted a study with a VAR model for different country groups and underlined a similar issue. On the other hand, some studies have concluded that foreign direct investments will increase in countries which have coal reserves. For example, Galindev et al. [3] and Huang et al. [8] conducted a study on Mongolia and China and concluded that foreign direct investments would increase in countries using coal energy.

2.4. Cost Effectiveness

Efficiency variables are based on the comparison of coal energy use with alternative energy sources. Cost efficiency, accessibility to coal and ease of processing of coal come to the forefront in the efficiency of the use of coal energy. As a result of these evaluations, the efficiency of coal energy is discussed. Wang et al. [45] examined the impact of coal use on economic performance within the cost framework. In this study, the hybrid life cycle assessment model was used, and it was found that the cost of coal was lower than that of biomass power. Similar studies were performed by Meng et al. [46] and it was determined that the use of coal energy reduces costs. Garðarsdóttir et al. [47] examined the countries of the European Union and stated that the use of coal energy will provide a cost advantage. Bunn et al. [2] stated that low cost biomass coal reserves could be transformed for the UK using the Monte Carlo model. Regarding efficiency, easy access to reserves is another prominent advantage of coal energy. Acer and Yeldan [48] conducted a similar study in Turkey and emphasized the importance of the mentioned issues. Han et al. [49] and Yoro and Sekoai [50] examined the use of coal energy in Vietnam and South Africa and reached the same conclusion. In addition to these studies, some studies in the literature also stated that coal energy may be preferred because it is easier to operate [51,52]. In addition to these issues, it is also identified that there has been a decrease in the cost of renewable energy projects, especially in the recent years. This situation has attracted the attention of the investors to modern renewable power plants. This can cause that the popularity of coal fired power plants, especially old ones, to go down [53,54].

As a result of the literature review, it is seen that there are two different views on the use of coal energy. The first opinion on this issue states that the use of coal energy is harmful. According to this view, the use of coal causes air and water pollution and this leads to important diseases. On the

other hand, in the second opinion on coal energy use, economic benefits of using this energy are mentioned. In this context, emphasis is placed on low-cost use of coal energy, positive impact on the current account balance and increasing investments. As can be understood from these studies, the studies in the literature on coal energy have generally focused on a single positive or negative factor. In other words, these studies have basically tested a single hypothesis. Therefore, it is obvious that there is a need for a new study that considers both positive and negative aspects of coal energy use together. In this context, nine different criteria representing both positive and negative aspects of coal use were determined in this study. Therefore, it would be possible to test both hypotheses in this study. In addition, the IT2 DANP method will be considered for the first time in this study about the use of coal energy. This is another difference that this study provides compared to others.

3. An Analysis on Coal Energy Usage

In this section, first, IT2 fuzzy sets will be explained. After that, the theoretical information regarding IT2 fuzzy DANP methodology will be given. Additionally, the dimensions and criteria for the evaluation of coal energy are identified. On the other side, in the second part of this section, analysis results are presented.

3.1. Materials and Methods

IT2 fuzzy sets are mainly concerned with the aim of minimizing uncertainty in decision making process. In addition to this situation, it is also thought that complexity can also be modeled in this process so that more appropriate values can be reached [55,56]. IT2 fuzzy DANP methodology is a combination of DEMATEL and ANP approaches. Hence, it contains the advantages of both methods to solve the problems under the complex environment. In other words, inner dependency can be considered with the help of ANP methodology. In addition to this issue, impact-relation map can be generated by considering DEMATEL approach [57–59]. The mathematical operations of them are detailed on the Appendix A part.

In this study, three dimensions and nine criteria are defined to evaluate the effects of coal energy on sustainable economic development. For that, the dimensions and criteria are illustrated with supported literature and the factors are given in Table 1.

Table 1. The dimensions and criteria for the evaluation of coal energy.

Dimensions	Criteria	References
Social	Environmental Pollution Health Problems Demographic Effects	Wang et al. [11]; Oliveira et al. [12] Habib et al. [21]; Tong et al. [22] Chen and Chen [7]; Teng et al. [26]
Economic	Employment Investment Current Account Balance	Aragon et al. [1]; Bohlmann et al. [28] Fan et al. [41]; Matyjaszek et al. [43] Figueiredo et al. [35]; Przychodzen and Przychodzen [38]
Efficiency	Lower Cost Easy Access to Reach Easy to Process	Meng et al. [46]; Garðarsdóttir et al. [47] Han et al. [49]; Yoro and Sekoai [50] Noble and Luttrell [51]; Oladejo et al. [52]

For this purpose, three decision makers are selected for providing linguistic evaluations for each dimension and criterion. In most of the studies where fuzzy MCDM approaches are accounted, the evaluations of three different experts are considered. Hence, it is thought that the number of the experts in this study are enough to make evaluation. These people are experts in the coal energy industry with at least ten-year experience. Additionally, these people consist of middle managers in this industry and academicians that make studies for this subject. Hence, it is understood that these experts can evaluate and measuring the effectiveness of the coal market. They give their priorities to construct the direct relation matrices by using the scales in Table 2. Linguistic evaluations of dimensions and

criteria are shown in the Appendix A (Tables A1 and A2) respectively. In these tables, three different experts are named as DM1, DM2 and DM3.

Table 2. Scales and fuzzy numbers for evaluations.

Linguistic Evaluations	Interval Type 2 Fuzzy Numbers
Very very low (VVL)	((0, 0.1, 0.1, 0.2, 1, 1), (0.05, 0.1, 0.1, 0.15, 0.9, 0.9))
Very low (VL)	((0.1, 0.2, 0.2, 0.35, 1, 1), (0.15, 0.2, 0.2, 0.3, 0.9, 0.9))
Low (L)	((0.2, 0.35, 0.35, 0.5, 1,1), (0.25, 0.35, 0.35, 0.45, 0.9, 0.9))
Medium (M)	((0.35, 0.5, 0.5, 0.65, 1, 1), (0.4, 0.5, 0.5, 0.6, 0.9, 0.9))
High (H)	((0.5, 0.65, 0.65, 0.8, 1, 1), (0.55, 0.65, 0.65, 0.75, 0.9, 0.9))
Very high (VH)	((0.65, 0.8, 0.8, 0.9, 1, 1), (0.7, 0.8, 0.8, 0.85, 0.9, 0.9))
Very very high (VVH)	((0.8, 0.9, 0.9, 1; 1, 1), (0.85, 0.9, 0.9, 0.95, 0.9, 0.9))

Source: Chen and Lee [60].

3.2. Analysis Results

IT2 fuzzy DANP is applied for weighting the dimensions and criteria. The novelty of this study is to modify the DANP method into trapezoidal fuzzy numbers. Thus, it could be possible to analyze the impact-relation degrees and interdependences among the factors with this extended approach. Additionally, more accurate results could be appointed by using IT2 fuzzy numbers instead of triangular fuzzy sets. For this purpose, the direct relation matrices for the dimensions and criteria are constructed with the converted values of expert opinions into the trapezoidal fuzzy numbers. And then, the computation procedure of DANP is considered to weight the criteria and dimensions accordingly. Tables A3 and A4 represent the fuzzy initial direct relation matrices of dimensions and criteria respectively. The averaged values of expert evaluations are used for the relation matrices. In the following steps, normalization procedure is applied for obtaining the defuzzified values of total relation matrix. Tables 3 and 4 show the total relation matrix for the dimensions and criteria.

Table 3. Total relation matrix for the dimensions.

	Dimension 1	Dimension 2	Dimension 3
Dimension 1	0.41	0.45	0.34
Dimension 2	1.03	0.46	0.64
Dimension 3	1.01	0.64	0.38

Table 4. Total relation matrix for the criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Criterion 1	0.10	0.23	0.24	0.19	0.23	0.25	0.26	0.25	0.25
Criterion 2	0.18	0.12	0.26	0.25	0.22	0.23	0.25	0.24	0.23
Criterion 3	0.13	0.15	0.10	0.17	0.13	0.14	0.15	0.13	0.12
Criterion 4	0.10	0.11	0.17	0.09	0.13	0.15	0.16	0.15	0.12
Criterion 5	0.10	0.11	0.14	0.12	0.08	0.12	0.13	0.14	0.13
Criterion 6	0.11	0.11	0.16	0.16	0.15	0.10	0.17	0.17	0.17
Criterion 7	0.11	0.14	0.18	0.19	0.20	0.17	0.11	0.19	0.18
Criterion 8	0.12	0.13	0.20	0.19	0.19	0.17	0.19	0.11	0.17
Criterion 9	0.11	0.12	0.18	0.18	0.19	0.18	0.18	0.18	0.10

In the next step of DANP based on interval type 2 fuzzy sets, the unweighted values of supermatrixes are computed and the results are given in Tables 5 and 6.

Table 5. Unweighted supermatrix for the dimensions.

	Dimension 1	Dimension 2	Dimension 3
Dimension 1	0.34	0.48	0.50
Dimension 2	0.38	0.22	0.32
Dimension 3	0.29	0.30	0.19

Table 6. Unweighted supermatrix for the criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Criterion 1	0.18	0.32	0.34	0.26	0.29	0.30	0.25	0.26	0.26
Criterion 2	0.40	0.21	0.40	0.30	0.32	0.29	0.33	0.30	0.30
Criterion 3	0.41	0.47	0.26	0.44	0.39	0.41	0.42	0.44	0.43
Criterion 4	0.29	0.36	0.38	0.25	0.38	0.39	0.34	0.35	0.33
Criterion 5	0.34	0.31	0.30	0.36	0.25	0.37	0.35	0.35	0.34
Criterion 6	0.37	0.33	0.32	0.39	0.37	0.23	0.31	0.30	0.32
Criterion 7	0.34	0.34	0.38	0.37	0.33	0.33	0.24	0.40	0.38
Criterion 8	0.33	0.34	0.33	0.34	0.35	0.33	0.40	0.24	0.40
Criterion 9	0.33	0.32	0.29	0.29	0.32	0.34	0.37	0.36	0.22

After this process, unweighted supermatrix is weighted based on the normalized values of total influence matrix and weighted results are shown in Table 7.

Table 7. Weighted supermatrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Criterion 1	0.06	0.11	0.11	0.12	0.14	0.14	0.13	0.13	0.13
Criterion 2	0.14	0.07	0.14	0.15	0.15	0.14	0.16	0.15	0.15
Criterion 3	0.14	0.16	0.09	0.21	0.19	0.20	0.21	0.22	0.22
Criterion 4	0.11	0.13	0.14	0.05	0.08	0.08	0.11	0.11	0.11
Criterion 5	0.13	0.12	0.11	0.08	0.05	0.08	0.11	0.11	0.11
Criterion 6	0.14	0.12	0.12	0.09	0.08	0.05	0.10	0.10	0.10
Criterion 7	0.10	0.10	0.11	0.11	0.10	0.10	0.04	0.07	0.07
Criterion 8	0.10	0.10	0.10	0.10	0.10	0.10	0.07	0.04	0.07
Criterion 9	0.09	0.09	0.08	0.09	0.10	0.10	0.07	0.07	0.04

In the last step, the limit supermatrix is calculated by providing the long-term stability of matrix with a large power k. The values are presented in Table 8.

Table 8. Limit supermatrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Criterion 1	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
Criterion 2	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
Criterion 3	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172
Criterion 4	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107
Criterion 5	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Criterion 6	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Criterion 7	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
Criterion 8	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
Criterion 9	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083

According to the results, criterion 3 (employment), criterion 2 (demographic effects), and criterion 1 (health problems) have the best three priorities in the multidimensional evaluation of coal energy for the sustainable economic development. These criteria are also stated in the social dimension. However,

criterion 7 (lower cost), criterion 8 (easy access to reach), and criterion 9 (easy to process) that are listed in the efficiency dimension have the weakest importance among the multidimensional evaluation of coal energy. These results demonstrate that social impacts are widely considered for the coal energy investments based on the sustainable economic development.

4. Discussion

In this study, the impact of the use of coal energy on sustainable economic development is analyzed. There are two different views on this subject in the literature. The first view is that the use of coal energy will benefit the country economically. The main reason behind this view is that countries with coal mines can easily meet their energy needs. As these countries will not have to buy natural gas or oil from abroad, the balance of payments will not deteriorate. On the other hand, since they will not import energy from outside, there will be no exchange rate risk. The second opinion on this issue is that the use of coal energy adversely affects human health. As a result of the use of coal energy, carbon dioxide gas is released into the atmosphere. This situation causes people to develop respiratory diseases. In addition, the use of coal energy also leads to pollution of spring waters. This can also lead to diseases, as it will also affect people's drinking water.

It is determined that migration of people due to environmental pollution caused by coal energy is one of the most important problems. There are many studies in the literature emphasizing this issue. For example, Chen and Chen [7] stated that there may be regional migrations due to air pollution caused by coal use which caused the decline of the agricultural sector. In addition, Teng et al. [26] conducted a similar study for China and defined that people who flood near the coal mines will migrate to the city centers. On the other hand, Huang et al. [27] and Cardooso [5] also defined that the workers working in the coal mine had psychological problems.

Health problems and environmental pollution are another important factor to consider in the use of coal energy. It has been determined that air and water pollution caused by coal energy should be taken into consideration in the use of this energy. As it can be understood from this situation, if the use of coal energy does not prevent these problems, it is more appropriate not to use this type of energy. The important point is that problems such as health and pollution resulting from the use of coal energy have more weight than the economic benefits of this energy. As a result, it is concluded that the expenditures made for the treatment of diseases caused using coal energy are higher than the economic benefits of this energy. Therefore, if these problems are not solved, it is determined that coal energy does not actually have an economic benefit. Shen et al. [61] claimed that it is necessary to reach advanced technology level in coal energy in order to realize the carbon reduction potential of coal. In addition to this study, Mbedzi et al. [4] concluded that the use of coal for South Africa is costly due to the environment and health consequences. Similarly, Xie et al. [62] found that the use of coal energy causes various environmental problems.

When these results are taken into consideration, it is determined that the use of coal energy will not create an economic benefit unless the resulting environmental pollution and health problems are prevented. In this context, firstly, if the use of coal energy is insisted, the use of quality coal is recommended. It is known that especially poor-quality coal with high sulfur content pollutes the air and this situation poses a serious threat to human health. For this purpose, it would be appropriate for states to make legal arrangements prohibiting the use of this type of coal. In addition, carbon capture and storage technology developed in recent years prevents the release of carbon dioxide gas generated using coal energy into the air. Thus, it will be possible to reduce greenhouse gas emissions to a great extent. This will contribute to the reduction of the problems arising from the use of coal energy. It would be appropriate to make this situation mandatory by legal regulation. Finally, it is recommended that countries invest in renewable energy resources in order to ensure sustainability in energy production and consumption. In this context, it will be possible to generate energy without damaging the environment through renewable energy investments to be made in suitable locations.

On the other hand, thanks to renewable energy sources, countries will be able to generate their own energy and will not depend on foreign countries for energy supply.

The biggest limitation of this study is that it focuses only on coal energy. Therefore, it will be possible to make a comparative analysis by examining other sources such as natural gas in a new study. In addition, a review with renewable and non-renewable energy types is considered beneficial. On the other hand, another limitation of the study is that the analyzes are based on expert opinions. Therefore, it is thought that performing a numerical analysis in a new study will provide a different perspective. In this context, it is believed that cointegration or causality analysis between the use of coal energy and economic growth will also contribute.

5. Conclusions

We aimed to find the more important one among two different opinions in the literature concerning the use of coal energy. For this purpose, a wide literature review has been made and nine different criteria have been selected which affect the decision to use coal energy. These criteria represent social, economic and productivity dimensions. Hence, the research question of this study is whether the usage of coal is effective for the countries by considering all significant dimensions. Furthermore, the importance weights of the mentioned factors are determined by using IT2 fuzzy DANP method. According to the results, it is determined that social factors are more important than the others. Within this framework, criterion 3 (employment), criterion 2 (demographic effects), and criterion 1 (health problems) have the best three priorities in the multidimensional evaluation of coal energy for the sustainable economic development. On the other hand, it is also identified that criterion 7 (lower cost), criterion 8 (easy access to reach), and criterion 9 (easy to process) that are listed in the efficiency dimension have the weakest importance among the multidimensional evaluation of coal energy. This situation indicates that especially the internal migration problem caused using coal energy should be paid attention. Migration of people due to environmental pollution caused by coal energy is one of the most important problems. These results demonstrate that social impacts are widely considered for the coal energy investments based on the sustainable economic development. By considering these issues, it can be said that the usage of the coal leads to negative results in the long term. In other words, it is obvious that the coal energy does not create economic benefits for the countries if the necessary actions are not taken to minimize its negative impacts on the environmental issues.

Appendix A

IT2 Fuzzy Sets

A type 2 fuzzy set can be identified as A. On the other side, $\mu_{A(x,u)}$ gives information about the type-2 membership function. This fuzzy set can be explained in the Equation (A1). In this equation, x and u represent the elements in the fuzzy set:

$$A = \left\{ \left((x,u), \mu_{A(x,u)}\right) \middle| \forall_x \in X, \forall_u \in J_x \subseteq [0,1] \right\}, \text{ or } A = \int_{x \in X} \int_{u \in J_x} \mu_A(x,u)/(x,u) \, J_x \subseteq [0,1] \qquad \text{(A1)}$$

In this equation, type-2 membership function can take value between 0 and 1. In addition to this point, $\int$ is also replaced with Σ. Furthermore, in case of the fact that this membership function equals to 1, Equation (A2) can be taken into consideration:

$$A = \int_{x \in X} \int_{u \in J_x} 1/(x, u) \, J_x \subseteq [0, 1] \tag{A2}$$

The upper and lower membership functions (A_i^U, A_i^L) of an interval type-2 fuzzy set can be shown as in the Equation (A3). In this equation, A_i represents the IT2 fuzzy set. In addition, a_{i1}^U, ..., a_{i4}^L are the reference values of this set. Moreover, $H_j\left(A_i^L\right)$ gives information about the membership value.

$$A_i = \left(A_i^U, A_i^L\right) = \left(\left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1\left(A_i^U\right), H_2\left(A_i^U\right)\right), \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1\left(A_i^L\right), H_2\left(A_i^L\right)\right)\right) \tag{A3}$$

Furthermore, mathematical operations of IT2 fuzzy sets are demonstrated is Equations (A4)–(A8):

$$
\begin{aligned}
A_1 \oplus A_2 = \left(A_1^U, A_1^L\right) \ &\oplus \left(A_2^U, A_2^L\right) \\
= &\left(\left(a_{11}^U + a_{21}^U, a_{12}^U + a_{22}^U, a_{13}^U + a_{23}^U, a_{14}^U\right.\right. \\
&+ a_{24}^U; min\left(H_1\left(A_1^U\right), H_1\left(A_2^U\right)\right), min\left(H_2\left(A_1^U\right), H_2\left(A_2^U\right)\right)\right), \left(a_{11}^L + a_{21}^L, a_{12}^L\right. \\
&+ a_{22}^L, a_{13}^L + a_{23}^L, a_{14}^L \\
&\left.\left.+ a_{24}^L; min\left(H_1\left(A_1^L\right), H_1\left(A_2^L\right)\right), min\left(H_2\left(A_1^L\right), H_2\left(A_2^L\right)\right)\right)\right)
\end{aligned} \tag{A4}
$$

$$
\begin{aligned}
A_1 \ominus A_2 = \left(A_1^U, A_1^L\right) \ &\ominus \left(A_2^U, A_2^L\right) \\
= &\left(\left(a_{11}^U - a_{24}^U, a_{12}^U - a_{23}^U, a_{13}^U - a_{22}^U, a_{14}^U\right.\right. \\
&- a_{21}^U; min\left(H_1\left(A_1^U\right), H_1\left(A_2^U\right)\right), min\left(H_2\left(A_1^U\right), H_2\left(A_2^U\right)\right)\right), \left(a_{11}^L\right. \\
&- a_{24}^L, a_{12}^L - a_{23}^L, a_{13}^L - a_{22}^L, a_{14}^L \\
&\left.\left.- a_{21}^L; min\left(H_1\left(A_1^L\right), H_1\left(A_2^L\right)\right), min\left(H_2\left(A_1^L\right), H_2\left(A_2^L\right)\right)\right)\right)
\end{aligned} \tag{A5}
$$

$$
\begin{aligned}
A_1 \otimes A_2 = \left(A_1^U, A_1^L\right) \ &\otimes \left(A_2^U, A_2^L\right) \\
= &\left(\left(a_{11}^U \times a_{21}^U, a_{12}^U \times a_{22}^U, a_{13}^U \times a_{23}^U, a_{14}^U\right.\right. \\
&\times a_{24}^U; min\left(H_1\left(A_1^U\right), H_1\left(A_2^U\right)\right), min\left(H_2\left(A_1^U\right), H_2\left(A_2^U\right)\right)\right), \left(a_{11}^L\right. \\
&\times a_{21}^L, a_{12}^L \times a_{22}^L, a_{13}^L \times a_{23}^L, a_{14}^L \\
&\left.\left.\times a_{24}^L; min\left(H_1\left(A_1^L\right), H_1\left(A_2^L\right)\right), min\left(H_2\left(A_1^L\right), H_2\left(A_2^L\right)\right)\right)\right)
\end{aligned} \tag{A6}
$$

$$
\begin{aligned}
kA_1 = \left(k \times a_{11}^U, k \times a_{12}^U, k \times a_{13}^U, k \times a_{14}^U; H_1\left(A_1^U\right), H_2\left(A_1^U\right)\right), \left(k \times a_{11}^L, k \times a_{12}^L, k \times a_{13}^L, k\right. \\
\left.\times a_{14}^L; H_1\left(A_1^L\right), H_2\left(A_1^L\right)\right)
\end{aligned} \tag{A7}
$$

$$
\begin{aligned}
\frac{A_1}{k} = \left(\frac{1}{k} \times a_{11}^U, \frac{1}{k} \times a_{12}^U, \frac{1}{k} \times a_{13}^U, \frac{1}{k} \times a_{14}^U; H_1\left(A_1^U\right), H_2\left(A_1^U\right)\right), \left(\frac{1}{k} \times a_{11}^L, \frac{1}{k} \times a_{12}^L, \frac{1}{k} \times a_{13}^L, \frac{1}{k}\right. \\
\left.\times a_{14}^L; H_1\left(A_1^L\right), H_2\left(A_1^L\right)\right)
\end{aligned} \tag{A8}
$$

IT2 Fuzzy DANP

The first step is related to the creation of the direct relation matrix. For this purpose, the evaluations of the decision makers are used. On the other side, the second step includes the development of

the initial influence matrix (A) which is given in the Equation (A9). In this matrix, a represents all different elements.

$$
A = \begin{bmatrix}
a_{11} & a_{21} & a_{13} & \cdots & a_{1n} \\
a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\
a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn}
\end{bmatrix}
\tag{A9}
$$

Moreover, this matrix is normalized in the third step by using the Equations (A10) and (A11).

$$
N = \frac{A}{s}
\tag{A10}
$$

$$
s = max \left[\max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}, \quad \max_{1 \le j \le n} \sum_{i=1}^{n} a_{ij} \right]
\tag{A11}
$$

Additionally, the total influence matrix (T) is generated in the fourth step by considering the Equations (A12) and (A13).

$$
T = N + N^2 + N^2 + \cdots + N^h = N\left(I + N + N^2 + \cdots + N^{h-1}\right)(I - N)(I - N)^{-1}
\tag{A12}
$$

$$
T = N\left(I - N^h\right)(I - N)^{-1} = N(I - N)^{-1}, \text{ when } \lim_{h \to \infty} N^h = [0]_{n \times n}
\tag{A13}
$$

The fifth step is related to the defuzzification of the total influence matrix with the help of the Equation (A14):

$$
\begin{aligned}
&Def_T \\
&= \frac{\frac{(u_U - l_U) + (\beta_U \times m_{1U} - l_U) + (\alpha_U \times m_{2U} - l_U)}{4} + l_U + \left[\frac{(u_L - l_L) + (\beta_L \times m_{1L} - l_L) + (\alpha_L \times m_{2L} - l_L)}{4} + l_L \right]}{2}
\end{aligned}
\tag{A14}
$$

In this equation, the maximum membership degrees are named as α and β. On the other side, m_{1U} and m_{2U} give information about the second and third parameters of the upper membership function whereas for lower membership function, m_{1L} and m_{2L} are used. The sixth step gives information about the influential network relation map. Equations (A15)–(A17) are considered for this purpose:

$$
T = \left[t_{ij} \right]_{n \times n}, \quad i, j = 1, 2, \ldots, n
\tag{A15}
$$

$$
r = \left[\sum_{j=1}^{n} t_{ij} \right]_{n \times 1} = (r_i)_{n \times 1} = (r_1, \ldots, r_i, \ldots, r_n)
\tag{A16}
$$

$$
y = \left[\sum_{i=1}^{n} t_{ij} \right]_{1 \times n}' = (y_j)_{1 \times n}' = (y_1, \ldots, y_i, \ldots, y_n)
\tag{A17}
$$

In the seventh step, the unweighted super-matrix (W) is created with Equations (A18)–(A22):

$$
T_c = \begin{array}{c} \\ \\ \\ \\ \\ D_i \\ \\ \\ D_n \end{array}
\begin{array}{c} \\ \\ c_{11} \\ c_{12} \\ \vdots \\ c_{1m1} \\ \vdots \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array}
\begin{array}{ccccccc}
D_1 & & \cdots & D_j & \cdots & & D_n \\
c_{11} & c_{12} & \cdots & c_{1m1} & \cdots & c_{n1} & c_{n2} \cdots c_{nm_n} \\
\end{array}
\left[\begin{array}{ccccc}
T_c^{11} & \cdots & T_c^{1j} & \cdots & T_c^{1n} \\
\vdots & & \vdots & & \vdots \\
T_c^{i1} & \cdots & T_c^{ij} & \cdots & T_c^{in} \\
\vdots & & \vdots & & \vdots \\
T_c^{n1} & \cdots & T_c^{nj} & \cdots & T_c^{nn}
\end{array}\right]
\tag{A18}
$$

$$
T_c^\beta = \begin{array}{c} \\ \\ \\ \\ \\ D_i \\ \\ \\ D_n \end{array}
\begin{array}{c} \\ \\ c_{11} \\ c_{12} \\ \vdots \\ c_{1m1} \\ \vdots \\ c_{n1} \\ c_{n2} \\ \vdots \\ c_{nm_n} \end{array}
\begin{array}{ccccccc}
D_1 & & \cdots & D_j & \cdots & & D_n \\
c_{11} & c_{12} & \cdots & c_{1m1} & \cdots & c_{n1} & c_{n2} \cdots c_{nm_n} \\
\end{array}
\left[\begin{array}{ccccc}
T_c^{\beta 11} & \cdots & T_c^{\beta 1j} & \cdots & T_c^{\beta 1n} \\
\vdots & & \vdots & & \vdots \\
T_c^{\beta i1} & \cdots & T_c^{\beta ij} & \cdots & T_c^{\beta in} \\
\vdots & & \vdots & & \vdots \\
T_c^{\beta n1} & \cdots & T_c^{\beta nj} & \cdots & T_c^{\beta nn}
\end{array}\right]
\tag{A19}
$$

$$
d_i^{11} = \sum_{j=1}^{m_1} t_{cij}^{11}, \; i = 1, 2, \ldots, m_1
\tag{A20}
$$

$$
T_c^{\beta 11} = \left[\begin{array}{ccccc}
t_{c11}^{11}/d_1^{11} & \cdots & t_{c1j}^{11}/d_1^{11} & \cdots & t_{c1m_1}^{11}/d_1^{11} \\
\vdots & & \vdots & & \vdots \\
t_{ci1}^{11}/d_i^{11} & \cdots & t_{cij}^{11}/d_i^{11} & \cdots & t_{cim_1}^{11}/d_i^{11} \\
\vdots & & \vdots & & \vdots \\
t_{cm11}^{11}/d_{m_1}^{11} & \cdots & t_{cm1j}^{11}/d_{m_1}^{11} & \cdots & t_{cm1m1}^{11}/d_{m_1}^{11}
\end{array}\right]
$$

$$
= \left[\begin{array}{ccccc}
t_{c11}^{\beta 11} & \cdots & t_{c1j}^{\beta 11} & \cdots & t_{c1m_1}^{\beta 11} \\
\vdots & & \vdots & & \vdots \\
t_{ci1}^{\beta 11} & \cdots & t_{cij}^{\beta 11} & \cdots & t_{cim_1}^{\beta 11} \\
\vdots & & \vdots & & \vdots \\
t_{cm11}^{\beta 11} & \cdots & t_{cm1j}^{\beta 11} & \cdots & t_{cm1m1}^{\beta 11}
\end{array}\right]
\tag{A21}
$$

$$
W = (T_c^\beta)\prime =
\begin{array}{c}
\\
\\
\end{array}
\begin{array}{c}
 & & D_1 & \cdots & D_i & \cdots & D_n \\
 & & c_{11}\ c_{12} & \cdots\ c_{1m_1} & \cdots & c_{n1}\ c_{n2} & \cdots\ c_{nm_n} \\
\end{array}
$$

$$
\begin{array}{cc}
D_1 & \begin{array}{c} c_{11} \\ c_{12} \\ \vdots \\ \vdots \end{array} \\
D_j & \begin{array}{c} c_{1m_1} \\ \vdots \end{array} \\
\vdots & \begin{array}{c} c_{n1} \\ c_{n2} \\ \vdots \end{array} \\
D_n & c_{nm_n}
\end{array}
\begin{bmatrix}
W_{11} & \cdots & W_{i1} & \cdots & W_{n1} \\
\vdots & & \vdots & & \vdots \\
W_{1j} & \cdots & W_{ij} & \cdots & W_{nj} \\
\vdots & & \vdots & & \vdots \\
W_{1n} & \cdots & W_{in} & \cdots & W_{nn}
\end{bmatrix}
\tag{A22}
$$

The eight step includes the calculation of the weighted super-matrix W^β by using Equations (A23)–(A26):

$$
=
\begin{bmatrix}
t_{11}^{D_{11}} & \cdots & t_{1j}^{D_{1j}} & \cdots & t_{1m}^{D_{1m}} \\
\vdots & & \vdots & & \vdots \\
t_{i1}^{D_{i1}} & \cdots & t_{ij}^{D_{ij}} & \cdots & t_{im}^{D_{im}} \\
\vdots & & \vdots & & \vdots \\
t_{m1}^{D_{m1}} & \cdots & t_{mj}^{D_{mj}} & \cdots & t_{mm}^{D_{mm}}
\end{bmatrix}
\tag{A23}
$$

$$
d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}} \quad , i = 1, 2, \ldots, m
\tag{A24}
$$

$$
= \begin{bmatrix}
t_{11}^{D_{11}}/d_1 & \cdots & t_{1j}^{D_{1j}}/d_1 & \cdots & t_{1m}^{D_{1m}}/d_1 \\
\vdots & & \vdots & & \vdots \\
t_{i1}^{D_{i1}}/d_i & \cdots & t_{ij}^{D_{ij}}/d_i & \cdots & t_{im}^{D_{im}}/d_i \\
\vdots & & \vdots & & \vdots \\
t_{m1}^{D_{m1}}/d_m & \cdots & t_{mj}^{D_{mj}}/d_m & \cdots & t_{mm}^{D_{mm}}/d_m
\end{bmatrix}
$$

$$
= \begin{bmatrix}
t_{11}^{\beta_{11}} & \cdots & t_{1j}^{\beta_{1j}} & \cdots & t_{1m}^{\beta_{1m}} \\
\vdots & & \vdots & & \vdots \\
t_{i1}^{\beta_{i1}} & \cdots & t_{ij}^{\beta_{ij}} & \cdots & t_{im}^{\beta_{im}} \\
\vdots & & \vdots & & \vdots \\
t_{m1}^{\beta_{m1}} & \cdots & t_{mj}^{\beta_{mj}} & \cdots & t_{mm}^{\beta_{mm}}
\end{bmatrix}
\tag{A25}
$$

$$
= \begin{bmatrix}
t_{11}^{\beta_{11}} \times W_{11} & \cdots & t_{i1}^{\beta_{i1}} \times W_{i1} & \cdots & t_{m1}^{\beta_{m1}} \times W_{n1} \\
\vdots & & \vdots & & \vdots \\
t_{1j}^{\beta_{1j}} \times W_{1j} & \cdots & t_{ij}^{\beta_{ij}} \times W_{ij} & \cdots & t_{mj}^{\beta_{mj}} \times W_{nj} \\
\vdots & & \vdots & & \vdots \\
t_{1m}^{\beta_{1m}} \times W_{1n} & \cdots & t_{im}^{\beta_{im}} \times W_{in} & \cdots & t_{mm}^{\beta_{mm}} \times W_{nn}
\end{bmatrix}
\tag{A26}
$$

The final step is related to the generation of the limit super-matrix.

Table A1. Experts' evaluations for the dimensions.

	Dimension 1			Dimension 2			Dimension 3		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
Social (Dimension 1)	-	-	-	M	VL	L	VL	VVL	VL
Economic (Dimension 2)	VH	H	H	-	-	-	M	M	M
Efficiency (Dimension 3)	VH	H	VH	L	M	L	-	-	-

Table A2. Experts' evaluations for the criteria.

	Criterion 1			Criterion 2			Criterion 3			Criterion 4			Criterion 5		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
Criterion 1	-	-	-	VH	H	VH	VH	VHH	VH	VHH	VHH	VH	M	M	H
Criterion 2	M	M	M	-	-	-	VH	H	VH	H	H	VH	M	M	M
Criterion 3	M	VL	M	M	VL	VH	-	-	-	M	M	M	VL	L	VL
Criterion 4	VL	L	VVL	VVL	VL	M	M	M	M	-	-	-	VL	L	L
Criterion 5	VL	L	L	L	VL	L	M	L	VL	VL	VL	L	-	-	-
Criterion 6	L	L	VL	VL	VL	VL	M	VL	L	L	L	M	VL	M	L
Criterion 7	VL	VL	VL	VL	L	M	M	L	M	L	M	VH	VH	M	M
Criterion 8	VL	VL	L	VL	L	L	H	M	M	M	M	H	VH	M	L
Criterion 9	L	VL	VVL	VL	L	VL	M	M	L	L	M	H	M	M	H

	Criterion 6			Criterion 7			Criterion 8			Criterion 9		
	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3	DM1	DM2	DM3
Criterion 1	H	H	VH	VH	H	H	M	VH	VH	H	VH	VH
Criterion 2	H	M	H	H	H	H	H	M	VH	H	H	M
Criterion 3	VL	VL	M	M	M	VVL	VL	L	VL	VL	VL	VVL
Criterion 4	M	VL	M	M	M	L	M	VVL	M	L	VL	VL
Criterion 5	L	VL	VL	L	VL	L	L	L	L	L	L	VL
Criterion 6	-	-	-	L	M	M	VL	M	H	M	M	H
Criterion 7	M	M	L	-	-	-	M	M	H	M	M	M
Criterion 8	M	VL	M	M	M	M	-	-	-	L	M	M
Criterion 9	M	M	M	M	L	M	L	M	H	-	-	-

Table A3. Fuzzy direct relation matrix for the dimensions.

	D1	D2	D3
D1	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.22, 0.35, 0.35, 0.50; 1,1), (0.27, 0.35, 0.35, 0.45; 0.90, 0.90))	((0.07, 0.17, 0.17, 0.30; 1, 1), (0.12, 0.17, 0.17, 0.25; 0.90, 0.90))
D2	((0.55, 0.70, 0.70, 0.83; 1, 1), (0.60, 0.70, 0.70, 0.78; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))
D3	((0.60, 0.75, 0.75, 0.87; 1, 1), (0.65, 0.75, 0.75, 0.82; 0.90, 0.90))	((0.25, 0.40, 0.40, 0.55; 1, 1), (0.30, 0.40, 0.40, 0.50; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))

Table A4. Fuzzy direct relation matrix for the criteria.

	C1	C2	C3	C4	C5
C1	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.60, 0.75, 0.75, 0.87; 1, 1), (0.65, 0.75, 0.75, 0.82; 0.90, 0.90))	((0.43, 0.53, 0.53, 0.60; 1, 1), (0.47, 0.53, 0.53, 0.57; 0.90, 0.90))	((0.22, 0.35, 0.35, 0.50; 1, 1), (0.27, 0.35, 0.35, 0.45; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))
C2	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.60, 0.75, 0.75, 0.87; 1, 1), (0.65, 0.75, 0.75, 0.82; 0.90, 0.90))	((0.55, 0.70, 0.70, 0.83; 1, 1), (0.60, 0.70, 0.70, 0.78; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))
C3	((0.27, 0.40, 0.40, 0.55; 1, 1), (0.32, 0.40, 0.40, 0.50; 0.90, 0.90))	((0.37, 0.50, 0.50, 0.63; 1, 1), (0.42, 0.50, 0.50, 0.58; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	((0.13, 0.25, 0.25, 0.40; 1, 1), (0.18, 0.25, 0.25, 0.35; 0.90, 0.90))
C4	((0.10, 0.22, 0.22, 0.35; 1, 1), (0.15, 0.22, 0.22, 0.30; 0.90, 0.90))	((0.15, 0.27, 0.27, 0.40; 1, 1), (0.20, 0.27, 0.27, 0.35; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.17, 0.30, 0.30, 0.45; 1, 1), (0.22, 0.30, 0.30, 0.40; 0.90, 0.90))
C5	((0.17, 0.30, 0.30, 0.45; 1, 1), (0.22, 0.30, 0.30, 0.40; 0.90, 0.90))	((0.17, 0.30, 0.30, 0.45; 1, 1), (0.22, 0.30, 0.30, 0.40; 0.90, 0.90))	((0.22, 0.35, 0.35, 0.50; 1, 1), (0.27, 0.35, 0.35, 0.45; 0.90, 0.90))	((0.13, 0.25, 0.25, 0.40; 1, 1), (0.18, 0.25, 0.25, 0.35; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))
C6	((0.17, 0.30, 0.30, 0.45; 1, 1), (0.22, 0.30, 0.30, 0.40; 0.90, 0.90))	((0.10, 0.22, 0.22, 0.35; 1, 1), (0.15, 0.22, 0.22, 0.30; 0.90, 0.90))	((0.22, 0.35, 0.35, 0.50; 1, 1), (0.27, 0.35, 0.35, 0.45; 0.90, 0.90))	((0.25, 0.40, 0.40, 0.55; 1, 1), (0.30, 0.40, 0.40, 0.50; 0.90, 0.90))	((0.22, 0.35, 0.35, 0.50; 1, 1), (0.27, 0.35, 0.35, 0.45; 0.90, 0.90))
C7	((0.10, 0.22, 0.22, 0.35; 1, 1), (0.15, 0.22, 0.22, 0.30; 0.90, 0.90))	((0.22, 0.35, 0.35, 0.50; 1, 1), (0.27, 0.35, 0.35, 0.45; 0.90, 0.90))	((0.30, 0.45, 0.45, 0.60; 1, 1), (0.35, 0.45, 0.45, 0.55; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))	((0.45, 0.60, 0.60, 0.75; 1, 1), (0.50, 0.60, 0.60, 0.70; 0.90, 0.90))

Table A4. *Cont.*

	C1	C2	C3	C4	C5
C8	((0.13, 0.25, 0.25, 0.40; 1, 1), (0.18, 0.25, 0.25, 0.35; 0.90, 0.90))	((0.17, 0.30, 0.30, 0.45; 1, 1), (0.22, 0.30, 0.30, 0.40; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))
C9	((0.10, 0.22, 0.22, 0.35; 1, 1), (0.15, 0.22, 0.22, 0.30; 0.90, 0.90))	((0.13, 0.25, 0.25, 0.40; 1, 1), (0.18, 0.25, 0.25, 0.35; 0.90, 0.90))	((0.30, 0.45, 0.45, 0.60; 1, 1), (0.35, 0.45, 0.45, 0.55; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))
	C6	C7	C8	C9	
C1	((0.55, 0.70, 0.70, 0.83; 1, 1), (0.60, 0.70, 0.70, 0.78; 0.90, 0.90))	((0.55, 0.70, 0.70, 0.83; 1, 1), (0.60, 0.70, 0.70, 0.78; 0.90, 0.90))	((0.55, 0.70, 0.70, 0.83; 1, 1), (0.60, 0.70, 0.70, 0.78; 0.90, 0.90))	((0.60, 0.75, 0.75, 0.87; 1, 1), (0.65, 0.75, 0.75, 0.82; 0.90, 0.90))	
C2	((0.45, 0.60, 0.60, 0.75; 1, 1), (0.50, 0.60, 0.60, 0.70; 0.90, 0.90))	((0.50, 0.65, 0.65, 0.80; 1, 1), (0.55, 0.65, 0.65, 0.75; 0.90, 0.90))	((0.50, 0.65, 0.65, 0.80; 1, 1), (0.55, 0.65, 0.65, 0.75; 0.90, 0.90))	((0.45, 0.60, 0.60, 0.75; 1, 1), (0.50, 0.60, 0.60, 0.70; 0.90, 0.90))	
C3	((0.18, 0.30, 0.30, 0.45; 1, 1), (0.23, 0.30, 0.30, 0.40; 0.90, 0.90))	((0.23, 0.37, 0.37, 0.50; 1, 1), (0.28, 0.37, 0.37, 0.45; 0.90, 0.90))	((0.13, 0.25, 0.25, 0.40; 1, 1), (0.18, 0.25, 0.25, 0.35; 0.90, 0.90))	((0.07, 0.17, 0.17, 0.30; 1, 1), (0.12, 0.17, 0.17, 0.25; 0.90, 0.90))	
C4	((0.27, 0.40, 0.40, 0.55; 1, 1), (0.32, 0.40, 0.40, 0.50; 0.90, 0.90))	((0.30, 0.45, 0.45, 0.60; 1, 1), (0.35, 0.45, 0.45, 0.55; 0.90, 0.90))	((0.23, 0.37, 0.37, 0.50; 1, 1), (0.28, 0.37, 0.37, 0.45; 0.90, 0.90))	((0.13, 0.25, 0.25, 0.40; 1, 1), (0.18, 0.25, 0.25, 0.35; 0.90, 0.90))	
C5	((0.13, 0.25, 0.25, 0.40; 1, 1), (0.18, 0.25, 0.25, 0.35; 0.90, 0.90))	((0.17, 0.30, 0.30, 0.45; 1, 1), (0.22, 0.30, 0.30, 0.40; 0.90, 0.90))	((0.20, 0.35, 0.35, 0.50; 1.00, 1.00), (0.25, 0.35, 0.35, 0.45; 0.90, 0.90))	((0.17, 0.30, 0.30, 0.45; 1, 1), (0.22, 0.30, 0.30, 0.40; 0.90, 0.90))	
C6	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.30, 0.45, 0.45, 0.60; 1, 1), (0.35, 0.45, 0.45, 0.55; 0.90, 0.90))	((0.32, 0.45, 0.45, 0.60; 1.00, 1.00), (0.37, 0.45, 0.45, 0.55; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))	
C7	((0.30, 0.45, 0.45, 0.60; 1, 1), (0.35, 0.45, 0.45, 0.55; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.40, 0.55, 0.55, 0.70; 1, 1), (0.45, 0.55, 0.55, 0.65; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	
C8	((0.27, 0.40, 0.40, 0.55; 1, 1), (0.32, 0.40, 0.40, 0.50; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	((0.30, 0.45, 0.45, 0.60; 1, 1), (0.35, 0.45, 0.45, 0.55; 0.90, 0.90))	
C9	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	((0.30, 0.45, 0.45, 0.60; 1, 1), (0.35, 0.45, 0.45, 0.55; 0.90, 0.90))	((0.35, 0.50, 0.50, 0.65; 1.00, 1.00), (0.40, 0.50, 0.50, 0.60; 0.90, 0.90))	((0, 0, 0, 0; 1, 1), (0, 0, 0, 0; 0.90, 0.90))	

References

1. Aragón, F.M.; Rud, J.P.; Toews, G. Resource shocks, employment, and gender: Evidence from the collapse of the UK coal industry. *Labour Econ.* **2018**, *52*, 54–67. [CrossRef]
2. Bunn, D.W.; Redondo-Martin, J.; Muñoz-Hernandez, J.I.; Diaz-Cachinero, P. Analysis of coal conversion to biomass as a transitional technology. *Renew. Energy* **2019**, *132*, 752–760. [CrossRef]
3. Galindev, R.; Baatarzorig, T.; Batbayar, N.; Begz, D.; Davaa, U.; Tserendorj, O. The Economic and Environmental Impact of Foreign Direct Investment on the Mongolian Coal-Export Sector. *Partnersh. Econ. Policy Work. Pap.* **2019**. [CrossRef]
4. Mbedzi, M.; van der Poll, H.; van der Poll, J. An Information Framework for Facilitating Cost Saving of Environmental Impacts in the Coal Mining Industry in South Africa. *Sustainability* **2018**, *10*, 1690. [CrossRef]
5. Cardoso, A. Behind the life cycle of coal: Socio-environmental liabilities of coal mining in Cesar, Colombia. *Ecol. Econ.* **2015**, *120*, 71–82. [CrossRef]
6. Minichilli, F.; Gorini, F.; Bustaffa, E.; Cori, L.; Bianchi, F. Mortality and hospitalization associated to emissions of a coal power plant: A population-based cohort study. *Sci. Total Environ.* **2019**, *694*, 133757. [CrossRef]
7. Clark, R.; Zucker, N.; Urpelainen, J. The future of coal-fired power generation in Southeast Asia. *Renew. Sustain. Energy Rev.* **2020**, *121*, 109650. [CrossRef]
8. Huang, X.; Chen, H.; Long, R.; Li, S. Development and validation of the quality of life scale for Chinese coal miners with pneumoconiosis (QOL-CMP): Measurement method and empirical study. *J. Clean. Prod.* **2019**, *232*, 1062–1075. [CrossRef]
9. Dinçer, H.; Yüksel, S.; Martínez, L. Interval type 2-based hybrid fuzzy evaluation of financial services in E7 economies with DEMATEL-ANP and MOORA methods. *Appl. Soft Comput.* **2019**, *79*, 186–202. [CrossRef]
10. Shukla, A.K.; Yadav, M.; Kumar, S.; Muhuri, P.K. Veracity handling and instance reduction in big data using interval type-2 fuzzy sets. *Eng. Appl. Artif. Intell.* **2020**, *88*, 103315. [CrossRef]
11. Wang, B.; Cui, C.Q.; Zhao, Y.X.; Yang, B.; Yang, Q.Z. Carbon emissions accounting for China's coal mining sector: Invisible sources of climate change. *Nat. Hazards* **2019**, *99*, 1345–1364. [CrossRef]
12. Oliveira, M.L.; Pinto, D.; Tutikian, B.F.; da Boit, K.; Saikia, B.K.; Silva, L.F. Pollution from uncontrolled coal fires: Continuous gaseous emissions and nanoparticles from coal mines. *J. Clean. Prod.* **2019**, *215*, 1140–1148. [CrossRef]
13. Shapiro, M.A.; Bolsen, T. Korean perceptions of transboundary air pollution and domestic coal development: Two framing experiments. *Energy Policy* **2019**, *126*, 333–342. [CrossRef]
14. Oskarsson, P.; Bedi, H.P. Extracting environmental justice: Countering technical renditions of pollution in India's coal industry. *Extr. Ind. Soc.* **2018**, *5*, 340–347. [CrossRef]
15. Wu, D.; Ma, X.; Zhang, S. Integrating synergistic effects of air pollution control technologies: More cost-effective approach in the coal-fired sector in China. *J. Clean. Prod.* **2018**, *199*, 1035–1042. [CrossRef]
16. Li, J.; Zhang, Y.; Tian, Y.; Cheng, W.; Yang, J.; Xu, D.; Wang, Y.; Xie, K.; Ku, A.Y. Reduction of carbon emissions from China's coal-fired power industry: Insights from the province-level data. *J. Clean. Prod.* **2020**, *242*, 118518.
17. Feng, Q.; Huang, Q.; Zheng, Q.; Lu, L. New Carbon Emissions Allowance Allocation Method Based on Equilibrium Strategy for Carbon Emission Mitigation in the Coal-Fired Power Industry. *Sustainability* **2018**, *10*, 2923. [CrossRef]
18. Munawer, M.E. Human health and environmental impacts of coal combustion and post-combustion wastes. *J. Sustain. Min.* **2018**, *17*, 87–96. [CrossRef]
19. Wang, Y.; Chen, H.; Long, R.; Yang, M. Health economic loss measurement and risk assessment of new cases of coal worker's pneumoconiosis in China. *Saf. Sci.* **2020**, *122*, 104529. [CrossRef]
20. Roy, D.; Singh, G.; Seo, Y.C. Coal mine fire effects on carcinogenicity and non-carcinogenicity human health risks. *Environ. Pollut.* **2019**, *254*, 113091. [CrossRef]
21. Habib, M.A.; Islam, A.R.M.T.; Bodrud-Doza, M.; Mukta, F.A.; Khan, R.; Siddique, M.A.B.; Techato, K. Simultaneous appraisals of pathway and probable health risk associated with trace metals contamination in groundwater from Barapukuria coal basin, Bangladesh. *Chemosphere* **2020**, *242*, 125183. [CrossRef]
22. Tong, R.; Cheng, M.; Yang, X.; Yang, Y.; Shi, M. Exposure levels and health damage assessment of dust in a coal mine of Shanxi Province, China. *Saf. Environ. Prot.* **2019**, *128*, 184–192. [CrossRef]

23. Xiao, X.; Zhang, J.; Wang, H.; Han, X.; Ma, J.; Ma, Y.; Luan, H. Distribution and health risk assessment of potentially toxic elements in soils around coal industrial areas: A global meta-analysis. *Sci. Total Environ.* **2019**, *731*, 135292. [CrossRef] [PubMed]

24. Sun, D.; Fang, J.; Sun, J. Health-related benefits of air quality improvement from coal control in China: Evidence from the Jing-Jin-Ji region. *Resour. Conserv. Recycl.* **2018**, *129*, 416–423. [CrossRef]

25. Finkelman, R.B.; Tian, L. The health impacts of coal use in China. *Int. Geol. Rev.* **2018**, *60*, 579–589. [CrossRef]

26. Teng, M.; Burke, P.J.; Liao, H. The demand for coal among China's rural households: Estimates of price and income elasticities. *Energy Econ.* **2019**, *80*, 928–936. [CrossRef]

27. Huang, Y.; Zhang, Y.; Lin, L.; Wan, G. Foreign direct investment and cleaner production choice: Evidence from Chinese coal-fired power generating enterprises. *J. Clean. Prod.* **2019**, *212*, 766–778. [CrossRef]

28. Bohlmann, H.R.; Horridge, J.M.; Inglesi-Lotz, R.; Roos, E.L.; Stander, L. Regional employment and economic growth effects of South Africa's transition to low-carbon energy supply mix. *Energy Policy* **2019**, *128*, 830–837. [CrossRef]

29. Burke, P.J.; Best, R.; Jotzo, F. Closures of coal-fired power stations in Australia: Local unemployment effects. *Aust. J. Agric. Resour. Econ.* **2019**, *63*, 142–165. [CrossRef]

30. Lobao, L.; Zhou, M.; Partridge, M.; Betz, M. Poverty, place, and coal employment across Appalachia and the United States in a new economic era. *Rural Sociol.* **2016**, *81*, 343–386. [CrossRef]

31. Patrizio, P.; LeDuc, S.; Kraxner, F.; Fuss, S.; Kindermann, G.E.; Mesfun, S.; Spokas, K.; Mendoza-Ponce, A.; Mac Dowell, N.; Wetterlund, E.; et al. Reducing US coal emissions can boost employment. *Joule* **2018**, *2*, 2633–2648. [CrossRef]

32. Marcos-Martinez, R.; Measham, T.G.; Fleming-Muñoz, D.A. Economic impacts of early unconventional gas mining: Lessons from the coal seam gas industry in New South Wales, Australia. *Energy Policy* **2019**, *125*, 338–346. [CrossRef]

33. Scholz, D.; Zundel, S.; Müsgens, F. Price and Employment Effects triggered by a German Coal Phase-Out—A Discourse Analysis. In Proceedings of the 2019 16th International Conference on the European Energy Market (EEM), Ljubljana, Slovenia, 18–20 September 2019.

34. Winarno, T.; Drebenstedt, C. Indonesia economic output and employment impact of low rank coal utilization: An input output analysis. In *XVIII International Coal Preparation Congress*; Springer: Berlin/Heidelberg, Germany, 2016.

35. Figueiredo, R.; Nunes, P.; Meireles, M.; Madaleno, M.; Brito, M.C. Replacing coal-fired power plants by photovoltaics in the Portuguese electricity system. *J. Clean. Prod.* **2019**, *222*, 129–142. [CrossRef]

36. Berk, C.; Cin, K.O. On Energy Dependence, Current Account Deficit and Population in Turkey. *Open J. Bus. Manag.* **2018**, *6*, 183. [CrossRef]

37. Çıraklı, M.E. The Effect Of Utılızatıon of Domestıc Coal Resources on Turkey's Current Account Balance: An Example of Afsin-Elbistan Lıgnıtes. Master's Thesis, Hacettepe University, Ankara, Turkey, 2019.

38. Przychodzen, W.; Przychodzen, J. Determinants of renewable energy production in transition economies: A panel data approach. *Energy* **2019**, *191*, 116583. [CrossRef]

39. Mukherjee, A.; Maity, A.; Chatterjee, S. Enabling a gasification and carbon capture economy in India: An integrated techno-economic analysis. *Fuel* **2019**, *263*, 116595. [CrossRef]

40. Rokhim, R.; Adawiyah, W.; Nasution, R.E.F. The negative impact of coal mining company on health, environment, climate change, economic sustainability and macroeconomic. In Proceedings of the E3S Web of Conferences, Jakarta, Indonesia, 24–25 October 2018.

41. Fan, J.L.; Wei, S.; Zhang, X.; Yang, L. A comparison of the regional investment benefits of CCS retrofitting of coal-fired power plants and renewable power generation projects in China. *Int. J. Greenh. Gas Control* **2019**, *92*, 102858. [CrossRef]

42. Jiang, S.; Yang, C.; Guo, J.; Ding, Z. ARIMA forecasting of China's coal consumption, price and investment by 2030. *Energy Sources Part B: Econ. Plan. Policy* **2018**, *13*, 190–195. [CrossRef]

43. Matyjaszek, M.; Wodarski, K.; Krzemień, A.; García-Miranda, C.E.; Sánchez, A.S. Coking coal mining investment: Boosting European Union's raw materials initiative. *Resour. Policy* **2018**, *57*, 88–97. [CrossRef]

44. Yuan, J.; Li, X.; Xu, C.; Zhao, C.; Liu, Y. Investment risk assessment of coal-fired power plants in countries along the Belt and Road initiative based on ANP-Entropy-TODIM method. *Energy* **2019**, *176*, 623–640. [CrossRef]

45. Wang, C.; Zhang, L.; Zhou, P.; Chang, Y.; Zhou, D.; Pang, M.; Yin, H. Assessing the environmental externalities for biomass-and coal-fired electricity generation in China: A supply chain perspective. *J. Environ. Manag.* **2019**, *246*, 758–767. [CrossRef] [PubMed]

46. Meng, F.; Gao, L.; Yan, Y.; Cao, J.; Wang, N.; Wang, T.; Ma, T. Ultra-low-cost coal-based carbon electrodes with seamless interfacial contact for effective sandwich-structured perovskite solar cells. *Carbon* **2019**, *145*, 290–296. [CrossRef]

47. Garðarsdóttir, S.Ó.; Göransson, L.; Normann, F.; Johnsson, F. Improving the flexibility of coal-fired power generators: Impact on the composition of a cost-optimal electricity system. *Appl. Energy* **2018**, *209*, 277–289. [CrossRef]

48. Acar, S.; Yeldan, A.E. Environmental impacts of coal subsidies in Turkey: A general equilibrium analysis. *Energy Policy* **2016**, *90*, 1–15. [CrossRef]

49. Han, S.; Zhang, J.; Zhou, Y.; Bai, S.; Huang, L.; Wang, C.; Huang, W. Formation and accumulation of lower Jurassic tight gas sands field in Kekeya area of Tuha Basin, northwestern China. *J. Nat. Gas Sci. Eng.* **2016**, *29*, 101–109. [CrossRef]

50. Yoro, K.O.; Sekoai, P.T. The potential of CO_2 capture and storage technology in South Africa's coal-fired thermal power plants. *Environments* **2016**, *3*, 24. [CrossRef]

51. Noble, A.; Luttrell, G.H. A review of state-of-the-art processing operations in coal preparation. *Int. J. Min. Sci. Technol.* **2015**, *25*, 511–521. [CrossRef]

52. Oladejo, J.M.; Adegbite, S.; Pang, C.H.; Liu, H.; Parvez, A.M.; Wu, T. A novel index for the study of synergistic effects during the co-processing of coal and biomass. *Appl. Energy* **2017**, *188*, 215–225. [CrossRef]

53. Kåberger, T. Progress of renewable electricity replacing fossil fuels. *Glob. Energy Interconnect.* **2018**, *1*, 48–52.

54. Kost, C.; Mayer, J.N.; Thomsen, J.; Hartmann, N.; Senkpiel, C.; Philipps, S.; Nold, S.; Lude, S.; Saad, N.; Schlegl, T. Levelized cost of electricity renewable energy technologies. *Fraunhofer Inst. Sol. Energy Syst. ISE* **2013**, *144*, 1–42.

55. Zhou, P.; Zhou, P.; Yüksel, S.; Dinçer, H.; Uluer, G.S. Balanced Scorecard-Based Evaluation of Sustainable Energy Investment Projects with IT2 Fuzzy Hybrid Decision Making Approach. *Energies* **2020**, *13*, 82. [CrossRef]

56. Bernal, E.; Castillo, O.; Soria, J.; Valdez, F. Type-2 Fuzzy Logic for Dynamic Parameter Adaptation in the Imperialist Competitive Algorithm. In *Hybrid Intelligent Systems in Control, Pattern Recognition and Medicine*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 109–118.

57. Dinçer, H.; Hošková-Mayerová, Š.; Korsakienė, R.; Yüksel, S. IT2-based multidimensional evaluation approach to the signaling: Investors' priorities for the emerging industries. *Soft Comput.* **2019**, 1–18. [CrossRef]

58. Qiu, D.; Dinçer, H.; Yüksel, S.; Ubay, G.G. Multi-Faceted Analysis of Systematic Risk-Based Wind Energy Investment Decisions in E7 Economies Using Modified Hybrid Modeling with IT2 Fuzzy Sets. *Energies* **2020**, *13*, 1423. [CrossRef]

59. Çelikbilek, Y.; Adıgüzel Tüylü, A.N. Prioritizing the components of e-learning systems by using fuzzy DEMATEL and ANP. *Interact. Learn. Environ.* **2019**, 1–22. [CrossRef]

60. Chen, S.C.; Lee, A.H. Performance measurement of SMEs' employees by fuzzy multi-criteria decision theory. In Proceedings of the 2010 International Symposium on Computer, Communication, Control and Automation (3CA), Tainan, Taiwan, 5–7 May 2010.

61. Shen, Q.; Song, X.; Mao, F.; Sun, N.; Wen, X.; Wei, W. Carbon reduction potential and cost evaluation of different mitigation approaches in China's coal to olefin Industry. *J. Environ. Sci.* **2020**, *90*, 352–363. [CrossRef] [PubMed]

62. Xie, L.; Huang, Y.; Qin, P. Spatial distribution of coal-fired power plants in China. *Environ. Dev. Econ.* **2018**, *23*, 495–515. [CrossRef]