Assessment of Sintering Flue Gas Management Using Multi-Criteria Decision-Making Methodology

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Abstract

To evaluate and promote ecologically responsible practices in the sintering business, conducting a sustainability evaluation of sintering flue gas is essential. An important step in making iron and steel, sintering releases flue gas emissions that, if not controlled, may harm the environment. Reducing emissions, improving energy efficiency, managing waste, using water, utilizing resources, monitoring community effects, complying with regulations, conducting a life cycle assessment, and continuously improving are all part of the assessment's extensive scope. When these aspects are considered, stakeholders may better understand the economic, social, and environmental effects of sintering flue gas management. This paper used the multi-criteria decision-making (MCDM) methodology to evaluate the criteria. We used the DEMATEL method as an MCDM method. The DEMATEL is used to build the relation between the criteria. We collect ten criteria in this study. We compute the criteria weights to show this study's best and worst criterion. The DEMATEL method is used to draw the effect diagram between criteria.

Keywords: Multi-criteria Decision Making; Sustainability; Sintering Flue Gas; DEMATEL Method.

1. Introduction

To evaluate and promote ecologically responsible practices in the sintering business, the sustainability evaluation of sintering flue gas is crucial. Sintering is used to create iron and steel, which entails heating raw ingredients until they solidify. But if not controlled, the flue gas emissions from this process might severely damage the environment[1], [2].

It is now more important than ever to evaluate the long-term viability of sintering flue gas and find ways to make it better in light of rising worries about global warming, air pollution, and resource loss. Reducing emissions, managing waste, consuming water, utilizing resources, community impacts, ensuring regulatory compliance, conducting a life cycle assessment, and continuously improving are all thoroughly examined in a sustainability assessment[3], [4].

When these factors are considered, stakeholders may better understand the social, economic, and environmental effects of sintering flue gas management. The results of this evaluation can pinpoint problem areas, develop solutions, and encourage the use of sustainable practices that contribute to achieving global sustainability objectives[5], [6].

In addition to ensuring that sintering flue gas complies with requirements, a sustainability evaluation should lessen the process's impact on the environment by reducing resource consumption and encouraging more efficient use of

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energy and materials. It also acknowledges the significance of reducing the effects on neighbouring communities and protecting the health of sintering workers[7], [8].

Furthermore, it is essential to evaluate the sintering process from a life cycle viewpoint, considering both the process's upstream and downstream steps. By looking at it from every angle, we can comprehend the environmental effects of sintering flue gas, from the mining and shipping raw materials to manufacturing, consumption, and disposal[9], [10].

The sintering industry may find ways to innovate, undertake research, and collaborate with stakeholders to enhance sustainability performance by doing sustainability assessments. These evaluations are necessary to make better decisions, implement best practices, and move towards a more responsible and sustainable sintering sector[11], [12].

The sustainability assessment of sintering flue gas provides a thorough study of the sintering process's impact on the environment, society, and the economy. Stakeholders may create a better, more sustainable future by looking for ways to improve things, embracing a life cycle view, and evaluating various criteria[13], [14].

It has been shown that multi-criteria decision-making (MCDM) is a valuable tool for effective energy planning in addressing such complicated issues. While MCDA has its humorous rational roots in various fields, it mainly emerged from operations research, which uses multiple approaches. Numerous governmental and private sector choices concerning immigration, education, transportation, expenditures, surroundings, defense, health care, and other related fields have extensively used MCDA approaches[15]–[18].

In this study, we employed the DEMATEL method as an MCDM method for the analysis and evaluation of the criteria. The DEMATEL method is used to construct the relations between criteria.[19], [20]

2. Framework

In this section, we introduce the DEMATEL method as an MCDM method for the analysis of the criteria of SFG in a sustainable manner.

The Science and Human Affairs Program of the Battelle Memorial Institute of Geneva first established the decision-making trial and evaluation laboratory technique between 1972 and 1976 to research and resolve the complex and interrelated issue group. Using a hierarchical framework, the DEMATEL technique can enhance comprehension of the particular problem and the cluster of interconnected difficulties and aid in developing viable solutions. This approach, part of structural modeling, may find the interdependence of a system's parts using a causal diagram, in contrast to conventional methods like the analytical hierarchy process, which assumes that parts are autonomous[21], [22]. The causal diagram illustrates the interdependencies and relative strengths of variables using digraphs instead of a directionless graph. Figure 1 shows the steps of the DEMATEL method. The following are the steps of the DEMATEL method:

Figure 1: The steps of the DEMATEL method.

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Step 1. Build the direct reaction matrix

The direct relation matrix is built by experts and decision-makers by using a scale from 1 to 9.

Step 2. Normalize the direct relation matrix

The direct relation matrix is normalized by:

$$N = \frac{1}{\max_{1 \le i \le n} \sum_{j=1}^{n} x_{ij}} \quad (1)$$

$$S = N \times X \quad (2)$$

Where x_{ij} refers to the value in the direct relation matrix.

Step 3. Compute the total relation matrix

The total relation matrix is computed using the normalized direct relation matrix. The total relation matrix between the criteria and others.

$$T = S(I - S)^{-1} \quad (3)$$

Step 4. Compute the sum of rows and columns

We compute the sum of rows by R and the sum of columns by L as:

$$R = \left[\sum_{i=1}^{n} x_{ij}\right]_{1 \times n} \quad (4)$$

$$L = \left[\sum_{j=1}^{n} x_{ij}\right]_{1 \times n} \quad (5)$$

Step 5. Draw the effect diagram.

3. Results

In this section, we introduce the results of the DEMATEL method and the relationships between the criteria and others. We collected the ten criteria in this study. The descriptions of the criteria in this study are organized as:

SFC1. Emission Reduction: Determine how well the sintering flue gas treatment system lowers emissions of nitrogen oxides (NOx), heavy metals, particulate matter (PM), Sulphur dioxide (SO2), and other contaminants. Find out how well the system satisfies environmental goals and regulatory requirements.

SFC2. Regulatory Compliance: Maintain adherence to all applicable environmental, health, and safety, waste management, air emission, water quality, and national and international norms and laws. Take into account how well the reporting and monitoring systems work to verify compliance and ongoing progress.

SFC3. Continuous Improvement: Sintering flue gas treatment technology can only progress with the support of an innovative and improvement-oriented culture. In order to improve sustainability performance, think about investing in research and development, working with stakeholders, and using best practices.

SFC4. Occupational Health and Safety: Think about the safety procedures that are in place to ensure the health of the employees who will be handling the sintering and flue gas treatment processes. Evaluate the efficacy of PPE, training programmers, and safety procedures in maintaining a risk-free workplace.

SFC5. Waste Management: Examine the procedures for dealing with fly ash and scrubber sludge, two byproducts of flue gas treatment. To lessen negative effects on the environment and advance the concepts of the circular economy, think about ways to dispose of or utilize trash, such as recycling, reusing, or safe disposal.

SFC6. Life Cycle Assessment: To determine the full extent of the environmental effects, both immediate and long-term, it is necessary to do a life cycle evaluation on the sintering procedure and the flue gas treatment system. To find ways to make things better and make them more sustainable, think about raw material extraction, transportation, manufacture, use, and end-of-life management.

SFC7. Energy Efficiency: Determine how efficient the sintering process and its related flue gas treatment system are in terms of energy consumption. Think about how much power the machinery needs and

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whether or not you can get any use out of the flue gas. In order to lessen the impact on the environment and save resources, it is important to evaluate energy efficiency.

SFC8. Resource Utilization: Analyze how the sintering and flue gas treatment processes make use of various resources. Think about how well you're using resources like additives, fuels, or reagents, and see if there's a way to optimize or replace them to lessen your influence on the environment.

SFC9. Water Consumption: Figure out how much water the flue gas treatment system uses and where the water supply is. To reduce water use and possible contamination, think about how successful water management practices are, such as recycling and wastewater treatment.

SFC10. Community Impact: assess the possible effects on adjacent populations of sintering flue gas emissions, including odor, noise pollution, and air quality. Find out how successfully these safeguards worked to protect locals from these dangers.

Step 1. We build the direct reaction matrix between criteria as a comparison matrix. The experts evaluate the criteria by building the direct relation matrix. The experts used a scale from 1 to 9.

Step 2. Eqs. (1 and 2) is used to normalize the direct relation matrix as shown in Table 1

Table 1: The normalization direct relation matrix between criteria.

	SFC_1	SFC_2	SFC_3	SFC_4	SFC_5	SFC_6	SFC_7	SFC_8	SFC_9	SFC_{10}
SFC_1	0.018809	0.037618	0.056426	0.112853	0.169279	0.15047	0.131661	0.075235	0.056426	0.112853
SFC_2	0.009404	0.018809	0.037618	0.112853	0.094044	0.018809	0.037618	0.056426	0.037618	0.037618
SFC_3	0.00627	0.009404	0.018809	0.169279	0.112853	0.075235	0.094044	0.112853	0.15047	0.094044
SFC_4	0.003135	0.003135	0.00209	0.018809	0.15047	0.112853	0.075235	0.094044	0.169279	0.169279
SFC_5	0.00209	0.003762	0.003135	0.002351	0.018809	0.037618	0.112853	0.169279	0.112853	0.15047
SFC_6	0.002351	0.018809	0.004702	0.003135	0.009404	0.018809	0.056426	0.15047	0.169279	0.056426
SFC_7	0.002687	0.009404	0.003762	0.004702	0.003135	0.00627	0.018809	0.131661	0.15047	0.037618
SFC_8	0.004702	0.00627	0.003135	0.003762	0.00209	0.002351	0.002687	0.018809	0.131661	0.094044
SFC_9	0.00627	0.009404	0.002351	0.00209	0.003135	0.00209	0.002351	0.002687	0.018809	0.112853
SFC_{10}	0.003135	0.009404	0.003762	0.00209	0.002351	0.00627	0.009404	0.003762	0.003135	0.018809

Step 3. Eq. (3) is used to compute the total relation matrix as shown in Table 2.

Table 2: The total relation matrix.

	SFC_1	SFC_2	SFC_3	SFC_4	SFC_5	SFC_6	SFC_7	SFC_8	SFC_9	SFC_{10}
SFC_1	0.025051	0.052349	0.065673	0.139034	0.214871	0.191196	0.195604	0.196639	0.209877	0.244618
SFC_2	0.012784	0.025559	0.042342	0.128486	0.126663	0.046251	0.073896	0.116777	0.118637	0.116769
SFC_3	0.011752	0.020978	0.024754	0.183791	0.153444	0.111179	0.142046	0.201765	0.276725	0.218621
SFC_4	0.00771	0.013875	0.006886	0.025924	0.164189	0.1296	0.110814	0.1653	0.260282	0.261736
SFC_5	0.005582	0.011286	0.006616	0.007887	0.025513	0.0448	0.12592	0.204565	0.176232	0.207617

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SFC_6	0.005564	0.024909	0.008012	0.009882	0.017145	0.024911	0.066187	0.173756	0.216818	0.109767
SFC_7	0.005166	0.013786	6.06E-03	0.009304	0.008796	0.01072	0.024908	0.144272	0.183009	0.079445
SFC_8	0.006411	0.009609	4.91E-03	0.007254	0.006718	0.006211	0.007682	0.025467	0.143748	0.119331
SFC_9	0.007191	0.0116	3.90E-03	0.005384	0.007294	0.00556	0.007017	0.008518	0.025966	0.123101
SFC_{10}	0.003605	0.010499	0.004716	0.004782	0.005539	0.008557	0.012714	0.009815	0.010814	0.025277

Step 4. We compute the sum of rows and columns by using Eqs. (4 and 5). Then we compute the weights of the criteria as shown in Figure 2. We show that criterion 1 is the best and criterion 10 is the worst.

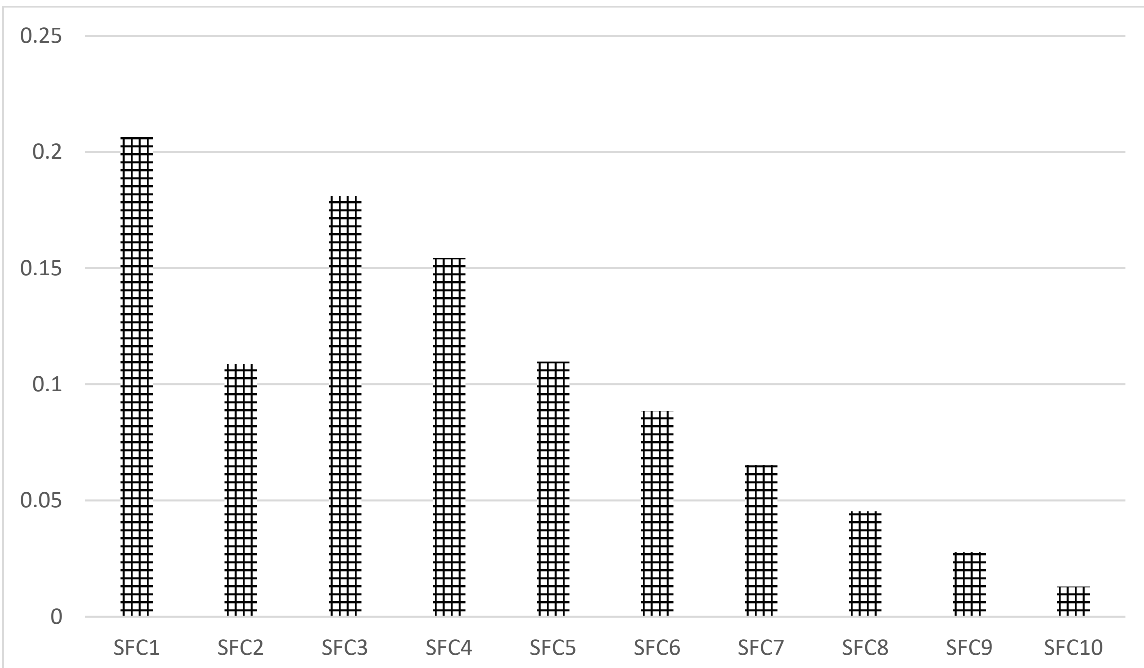

Figure 2: The weights of criteria.

We compute the sum of rows and columns as shown in Figures 3 and 4.

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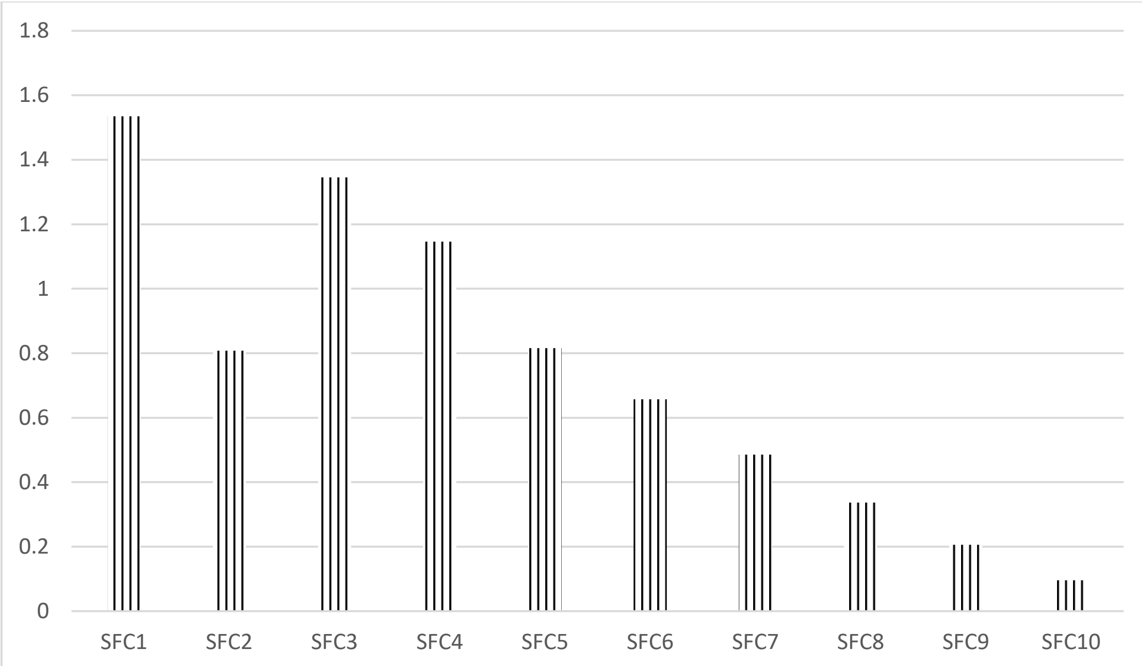

Figure 3: The sum of rows.

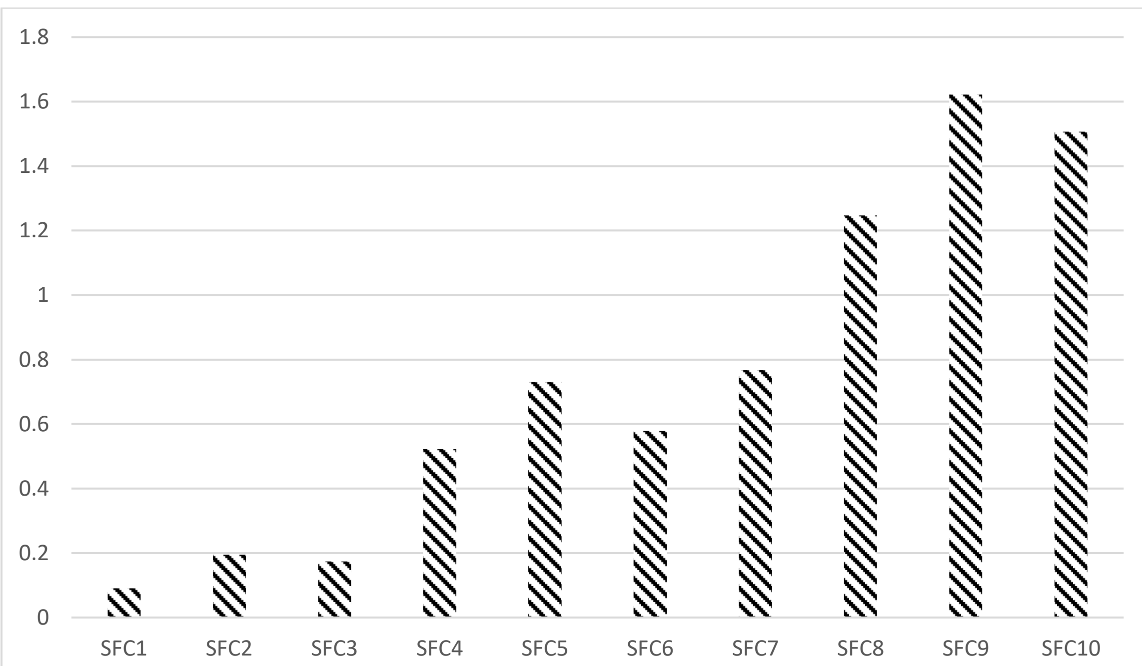

Figure 4: The sum of columns.

Step 5. We draw the effect diagram between criteria as shown in Figure 5.

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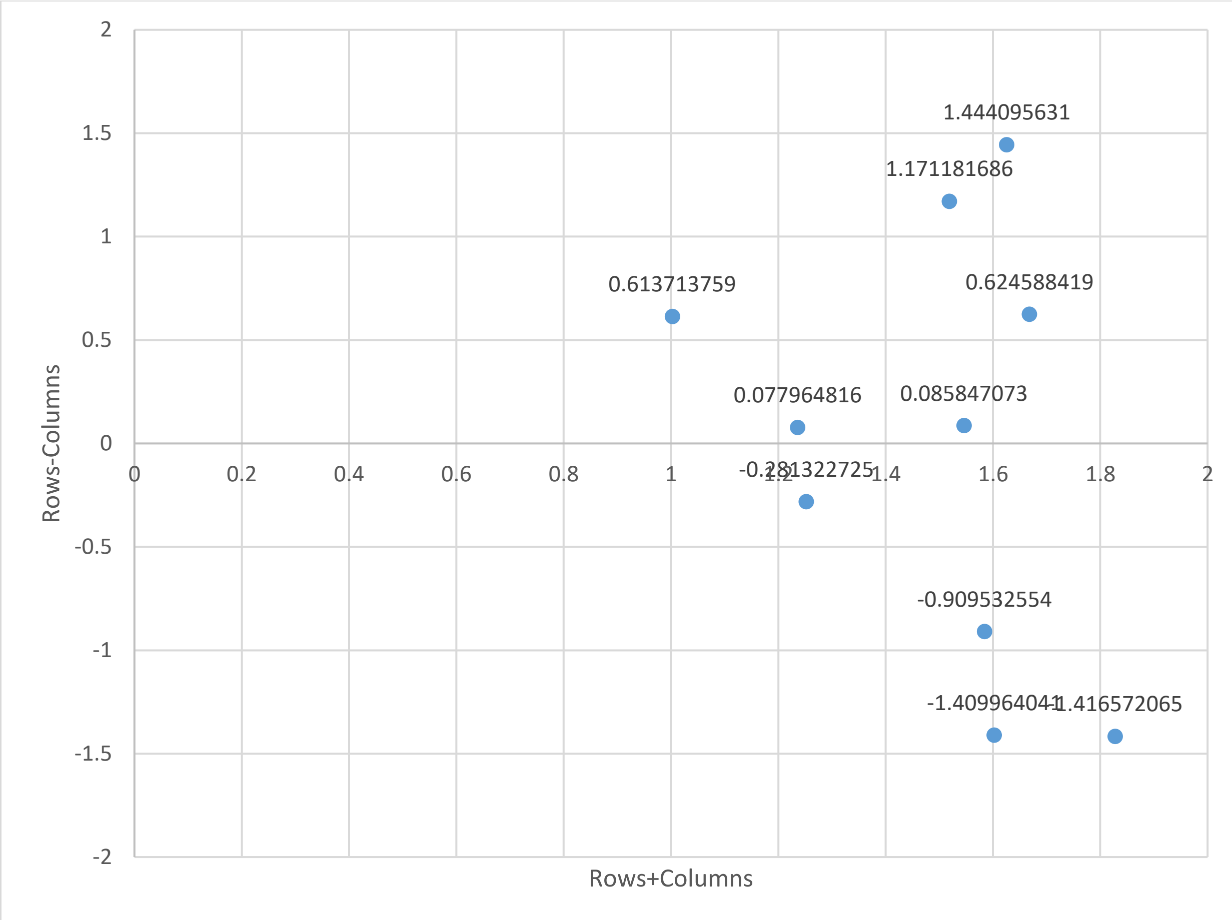

Figure 5: The effect diagram between criteria.

We let the experts evaluate the criteria of this study. We collected ten criteria in this study. We let the experts build the direct relation matrix between criteria and others. Then, we normalize the direct relation matrix to construct the normalized direct relation matrix, as shown in Table 2. Then, we compute the total relation matrix by using the values of the normalization direct relation matrix. Then, calculate the sum of rows and columns to show the effect diagram. Then, we compute the weights of the criteria. The weights show that criterion 1 is the best and criterion 10 is the worst. Then, we draw the effect diagram in Figure 5 to establish the relations between criteria.

4. Conclusions

If we want to know how sintering flue gas affects the environment and how the sector may become more sustainable, we must do a sustainability audit. Emissions reduction, energy efficiency, water consumption, resource utilization, community impact, regulatory compliance, life cycle assessment, and continuous improvement are vital criteria for a comprehensive assessment.

Sintering flue gas sustainably means reducing pollution, making the most of available energy, managing waste well, using as little water as possible, and making the most of what we have. Taking a life cycle approach to evaluate the whole environmental consequences is also necessary, as is protecting the health and safety of employees, reducing harmful effects on the local population, and meeting all applicable regulatory requirements.

The identification and implementation of improvement possibilities may be accelerated by sustainability evaluations, which drive innovation and encourage the use of advanced practices and technology. The sintering industry has steadily improved its sustainability performance through dedication to best practices, stakeholder engagement, and continuous improvement.

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Sustainability evaluations also help stakeholders make educated decisions that meet environmental standards, government mandates, and public expectations. A thorough comprehension of the ecological, societal, and financial elements of sintering flue gas may be attained by considering the whole spectrum of evaluation criteria.

Ultimately, a sustainability evaluation of sintering flue gas assists in propelling the sintering sector towards more responsible and sustainable practices. The circular economy, resource conservation, human health and safety, and lessening environmental consequences are all backed by this. We can help create a better, healthier, and longer-lasting future by prioritizing sustainability while managing sintering flue gas.

This paper evaluates the criteria of the sustainable SFG. We used the DEMATEL method to show the relation between the criteria. We collected ten criteria related to the SFG. We let experts evaluate the criteria to build the direct relation matrix. We compute the weights of the criteria. The results show that criterion 1 is the best and criterion 10 is the worst. We draw the effect diagram between criteria.

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