2023 IEEE International Conference on Multidisciplinary Research in Technology and Management
Bangalore,India, September 22-23, 2023

A HP-ETDM Model for Achieving Carbon Neutrality in Industrial Energy

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***Abstract*— In the development of green energy, Carbon neutrality is becoming increasingly important to energy companies needs to move forward urgently to realize the goal of carbon neutrality; This study examines the path to carbon neutrality in the energy sector. Qualitative methods combined with quantitative methods are employed in this study in order to provide methodological innovations in the existing literature on the transition of the energy industry to being carbon neutral. Energy industry systems are considered in this study to compiled authoritative case data on China's carbon neutral energy policy the transition, and then extracts word frequencies using keyword searches within the corpus for quantitative analysis using the corpus. To obtain the factors that influence the transformation of the industrial energy into a carbon neutral economy, the AHP model was built using the ETDM method, followed by further qualitative analysis, using the ETDM method. The influence and priority of those factors were further calculated. Using Corpus keywords and concordances, three types of typical cases were analyzed for validity and practicality. Actual cases were used to test the previously identified model as a result of the research, Management has the strongest relationship with other factors among those five factors influencing carbon neutralization; With a R+C 0.823. The negative values for Technology and Management indicate that they are both influenced by others. It can be concluded from analyzing these real-life cases that trading of carbon emissions, innovation, and digital revolution can contribute to the carbon neutrality of energy enterprises.**

Keywords*— *Carbon Neutrality, Energy Industry, ETDM, Digitalization.

I. Introduction

Today, carbon neutrality has become increasingly important to green energy developers. Climate change mitigation should be developed by all countries without significantly hindering economic growth in the future [1]. In 2020, China proposed becoming carbon neutral by 2060 by reaching its peak of carbon emissions by 2030. China, which has long been a fossil fuel consumer, can achieve carbon neutrality in two major ways. To reduce coal consumption, one energy with low carbon content must be increased; in order to do so, one must establish a high-quality market for trading carbon emissions[2]. The goal of "carbon neutrality" is a crucial one for promoting the sustainable development of all of society and the economy; and advancing the energy transition is a proven way of achieving the goal of carbon neutrality. Currently, electric heating dominates China's carbon emissions. China's carbon emissions are attributed to steel production to the tune of 15%, the highest among manufacturing industries. In terms of energy inputs, coal and coke make up nearly 90% of China's energy structure [3]. Our energy revolution must also promote a clean, low-carbon, safe, efficient, and reliable energy system, and we must improve energy supply systems so that we can achieve carbon neutrality[4].

II. CARBON NEUTRALITY AND ENERGY TRANSITION

To build a world that shares a future, carbon neutrality must be an objective, internal requirement. Researchers have conducted wide research on how to accomplish carbon neutrality in the academic community, with a focus mainly on optimizing industrial structures, adjusting energy structures, and researching low-carbon, green, and sustainable technologies, also promoting and developing them[5]. Financial and political support are crucial to the feasibility of energy carbon neutralization while energy-intensive industries decarbonize deeply[6]. In order to protect the environment and reduce traditional energy consumption, policy measures are relevant as a result; however, financial perspectives are also considered when analyzing and studying related industrial financing and investment opportunities[7].

It is unlikely that low-carbon energy will transform automatically, nor will carbon neutrality result from a brand new industrial revolution, according to academic circles[8]. All participants at global, national, and local levels must actively coordinate in order for them to occur. Maintaining effective control while achieving global carbon neutrality is possible[9]. When it comes to energy transition and carbon neutrality, carbon neutrality is generally recognized as a means of supporting economic and social sustainability. According to practice and theory, advancing the energy transition will lead to "carbon neutrality."

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Models using Markov chains are commonly used for predicting primary energy consumption[10]. It is necessary to use three different growth rates to determine whether and to what extent the target of carbon intensity can be met based on the amount of energy and greenhouse gases consumed. Modes of development that are stable and medium-speed indicate that adjusting the energy structure can contribute to the achievement of the carbon intensity target by 2030 if the Markov chain prediction is used[12].

To achieve carbon intensity and carbon neutrality targets, changes in the energy consumption structure are believed to be beneficial. A growth rate greater than 4.2% is required to achieve that. Researchers use infrastructure-based system planning models to model China's low-carbon transition path to carbon neutrality. Energy flows between the three regions based on the layout of the facilities, a carbon neutral energy system is dominated by the power and hydrogen systems. To meet emissions targets, carbon trading and new energy are essential, according to a National Academy of Sciences study. Carbon trading and new energy stock markets have been compared using a model developed by scholars[1]. In addition to having asymmetric spillover effects, new energy is a better source of network information. It is also more sensitive to negative price information when it is active. Due to the system's sensitivity to negative information, the spillover effect is more prominent when it is active. Researchers have argued that provinces' ability to reach their upper limits cost-effectively depends on how effective their allocation plans are. Energy consumption quotas can be allocated more generously to provinces with high start-up energy efficiency, as can a province with a lower renewable energy distribution than the national average. The energy structure should be adjusted, according to some of example from electricity to gas, by the academic community. Future energy systems in which carbon is reduced are proposed to use technology. Electricity-to-gas will be used as a research object to develop an open optimization model for future urban energy systems. A case study, combined with an open optimization mode, shows that electricity-to-gas can be beneficial. In order for a city to achieve carbon neutrality, energy-to-gas is used; Heat storage and transmission capacity are reduced by this technology. Sources of renewable energy, such as solar, wind, hydropower, nuclear, etc., will benefit from power structure adjustments, regardless of whether they are carbon neutral. In the opinion of some scholars, forest ecosystems are also a critical component of attaining the 30/60 carbon neutrality in the natural ecosystem context if observed from the analyzing view of natural ecosystems. Forests are one kind of Sites that store the most carbon on land and are the most important, wood forest products are an important part of carbon storage in terrestrial ecosystems, and they make up a significant portion of the carbon reserves on land. It is possible to achieve "carbon neutrality" in wood forest products via the carbon sink function of forests by utilizing effective methods to develop the product's carbon drop capacity. For quite some time, the academic community has studied an open world trade economy extensively.

According to a recent study, achieving carbon neutrality goals requires a close examination of the relationship between trade and carbon dioxide pollution. Reforms at the top of the economic pyramid should be designed to reduce economic complexity for the formation of trade policy. Investing in renewable energy resources and increasing the importance of green products are the path to sustainability. While exploring low-carbon development pathways, trade ports are also required to examine emerging trends in industrial growth and power consumption patterns. Ports with zero carbon emissions are one of them. Domestic regional industries should be considered when making relevant policies, policy makers should approach renewable energy consumption with an eye to promoting the use of renewable energy, and ensuring that carbon neutral targets can be adopted easily. In developed countries, green growth and carbon neutrality can only be achieved through ecological innovation, environmental taxes, and green energy[1].

Green taxation, eco-innovation, and green technology growth negatively affect global carbon dioxide emissions (CO2) from developing countries. An analysis of past and lagging CO2 emissions confirms a significant negative correlation. In related studies, the financial aspects were also considered, and it was revealed that a country's ability to consume renewable energy and achieve carbon neutrality depends on the growth of its financial development measures. Studies have also examined the financial aspect, concluding that a country's ability to achieve its renewable energy consumption and carbon neutrality goals is dependent upon financial development measures. As a result of the above literature review, academics have conducted substantial research on achieving carbon neutrality and energy transition. A theoretical framework and references have been gathered from those studies in order to conduct this study. In existing literature, large-scale corpora of multiple cases are rarely paired with qualitative analysis research; quantitative research is mainly applied to empirical models, and few studies combine qualitative and quantitative methods. A systemic approach is taken to studying the energy industry. For quantitative analysis, this paper collects official authoritative case data on China's transition to carbon neutrality in its energy sector, and extracts word frequencies from the corpus using keyword searches. Carbon neutrality is being achieved by a large number of energy companies using the corpus. Concordance is then used to perform qualitative analysis. An AHP model based on corpus results has been developed to analyze the factors affecting the transition of the energy industry to a carbon neutral economy. Combining quantitative and qualitative research to study the carbon neutrality in the electrical energy sector makes this study methodologically unique in the literature. Providing pragmatic examples of case studies for the energy industry and enterprises involved bears an important significance in the study of a large-scale case corpus.

III. MODEL AND METHODOLOGY

3.1 Construction of a corpus based on data sources

Real life examples of typical successful transitions to carbon neutrality are vital to identifying the different factors affecting the industry transition. These examples should be representative, authoritative, and accurate. From October 2020 to October 2021.

3.2 Key words in the corpus and steps for searching entries

Once the Word List has been screened and meta-words removed, a keyword attribute's relevance to a research theme is verified by using WordNet and PicData software. To determine the highest-ranking keywords can be obtained. Then, further corpus entries can be searched for and concordances can be built if such words are found. Identifying important influence paths begins with a Concordance hunt and study of the important factors that meet the criteria. In the third step, the key sentence composition form based on Concordance is further refined and preliminary analysis and discussion is conducted.

3.3 AHP model construction

Carbon neutrality can be achieved through the choice of specific transition schemes based on specific criteria by the energy industry and individual companies. Different carbon neutrality schemes must be evaluated, compared, and judged in order to make the best decision regarding carbon-neutral transition. The solution of mathematical problems has been greatly hindered by such subjective factors. It is a model and method for quantifying complex, difficult-to-understand systems called analytical hierarchy processes (AHP). Analyses are conducted using a hierarchical and systematic approach according to the AHP method. AHP's mathematicalization of the decision-making process is based on extensive research into complex decision-making problems. The use of unstructured decision-making problems can also facilitate the solution of multi-objective, multi-criteria, or complex decision-making problems. Energy industry transitions to carbon neutrality are analyzed using the AHP model.

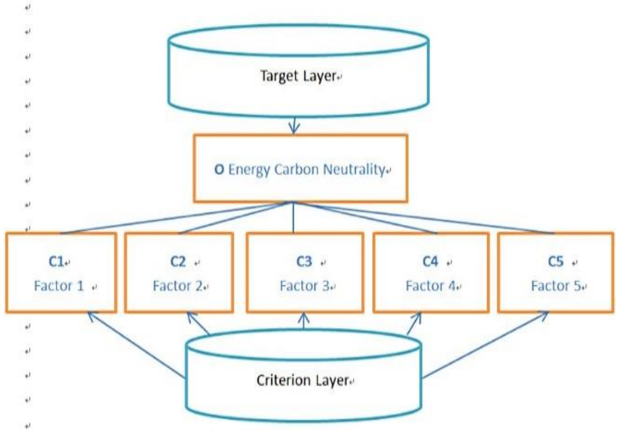

Fig. 1. AHP System

To achieve the overall goal of achieving a carbon neutral transition, and depends upon the principles of AHP, Fig.1 illustrates that this paper, according to the principles of AHP, Separates the components of the problem and, based on their interaction and affiliation relationship, a multi-level analysis structure model is developed by combining the factors at different levels. At the lowest level in relation to the highest target level.

3.4 ETDM method & steps

An analysis of system structure is simplified by using Evaluation and Trials of Decision Making (ETDM). It is widely used in conjunction with the AHP model. Choosing this method was a result of the point that we expect to use energy industry experts' expertise and Expertise in resolving complex issues of carbon neutralization, especially since in uncertain circumstances, AHP-ETDM is more effective. In the energy sector, many factors can influence a carbon neutral transition, and their relationships are unclear. Research indicators or factors must first be determined before conducting a study on the energy industry's transition to carbon neutrality. Quantify carbon neutrality's interactions with transition factors to obtain a direct influence matrix. The second step discusses how the original relationship matrix can be normalized to achieve a norm that directly affects it. The third step is to calculate an influence matrix. In order to determine how influential, central, and causing each factor is, the step four required to use of the comprehensive influence matrix. We will discuss and analyze the calculated cause degree and centrality based on the actual transition to carbon-neutrality in the energy industry.

IV RESULT

Checking the keyword attributes in the corpus to confirm they match the research theme. As shown in Fig. 2. The keyword attributes for carbon (Rank 4, Freq3715) and energy (Rank 7, Freq2021) are in the research theme except from the meta-words (such as the, and, of). By focusing on key words in the corpus, the corpus clearly promotes development in line with the objectives of the research.

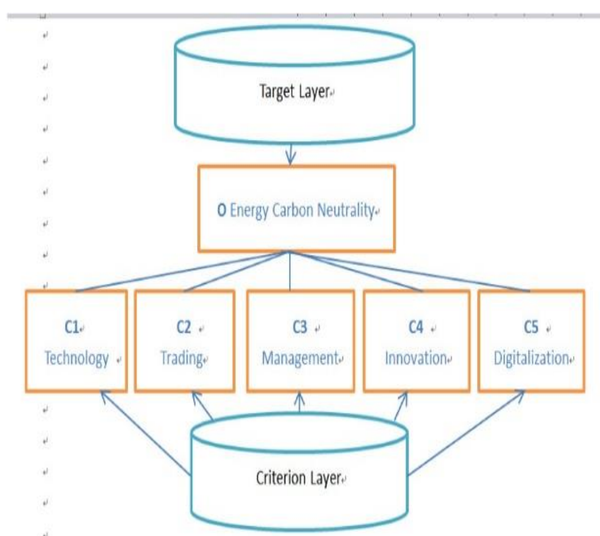

Fig. 2. Screening of the word list as a preliminary step.

The following five factors, Exceptions include meta-words and vocabulary that is not a factor, In the corpus search, these factors were significant influencing factors.

Table 1. Factors that influence the frequency and main factors.

Keywords	cater	Frequency
Technology	41	351
Trade	49	321
Management	76	203
Innovation approach	77	202
Digital revolution	85	181

The five key factors were used as a basis for a Concordance search analysis to identify important influence paths. Fig.3 provides an example of all five factors from the search for the factor Technology.

4.1 Results and evaluations for AHP based on influencing factors

After determining AHP indexes, importance index lists were identified, and scores were assigned.

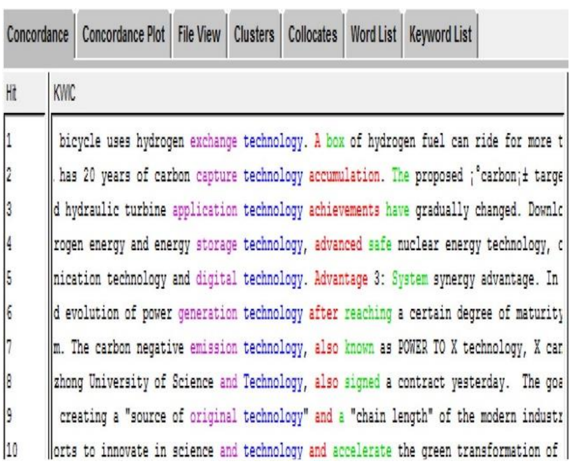

Fig. 3. The results of the search for the factor "Technology"

In this case, this following method is directly applied to three-level corresponding scores; there was no need to score from "not important". A judgment matrix was derived by comparing level indicators in pairs among 20 technical experts and field managers.

Matrix A =

$$\begin{array}{cccccc} & C1 & C2 & C3 & C4 & C5 \\ C1 & 1 & 5 & 3 & 3 & 0.2 \\ C2 & 0.2 & 1 & 5 & 5 & 5 \\ C3 & 0.3 & 0.2 & 1 & 0.5 & 0.3 \\ C4 & 0.3 & 0.2 & 2 & 1 & 1 \\ C5 & 5 & 0.2 & 3 & 1 & 1 \end{array}$$

The weight vector (eigenvector) is illustrated in Table 2 based on our results and weights assigned to various consistency indicators.

Table 2. influence and Centrality of each factors

Key word	Rank	Freq
Technology	1.33	-1.33
Trade	1.78	0.82
Management	1.85	-0.91
Innovation approach	1.84	0.66
Digital revolution	1.71	0.75

$$W = (0.286, 0.336, 0.048, 0.090, 0.240)^T$$

This indicates satisfied consistency because CI = 0.0065 X 0.10%. This value indicates satisfied consistency = 0.0058 x 0.10. According to Table C1, C1 has a weight of 0.2886; C2 has a weight of 0.333; C3 has a weight of 0.0448; C4 has a weight of 0.09; C5 has a weight of 0.240.

4.2 ETDM results and discussion

This table demonstrates the closest relationship between management and other factors, among those five factors that impact carbon neutralization. A priority in trading is trading, followed by a priority in digitalization (0.75), and a priority in innovation (0.66). The maximum RC value of 0.82 makes it the most influential factor. A negative value is observed for both "Technology" (1.33) and "Management" (0.91), indicating that they receive influence from other organizations. It can be seen that many decisions run through the industrial energy carbon neutrality, and that these choices are based on a systematic and dynamic process, and that decisions are at the heart of management. It is imperative to have decent scientific management for a "carbon neutral" energy industry, as evidenced by the results of the research. By establishing a top-level design management framework, various influencing factors will be managed effectively. All other factors are influenced most by carbon trading and are regarded as being of the highest priority. Therefore, it is evident that the carbon trading is critical in determining the direction in which the energy industry will move toward carbon neutrality. The decision-making process must also take this into account.

Conclusion

Based on carbon trade, innovation, and the digital revolution, there are three major paths to carbon neutrality in the energy sector. There is no way to separate these three paths, but they are all essential to each other. In the following, one of the influencing factors is highlighted in an overview of the three paths.

Path 1: Trading of carbon emissions

In the absence of carbon emission rights indicators, firms without sufficient carbon emissions will have to replace more carbon emissions to reach their emission reduction targets. By harnessing the "invisible hand" power of markets, carbon emissions trading can encourage energy firms to reducing of carbon emissions. Companies with outdated production capacity are forced to upgrade their technology through this mechanism. Using this mechanism, the country can achieve "carbon neutrality" by optimizing the industrial structure and promoting industrial energy transitions. As a Schneider Electric smart factory prototype and a Schneider Electric smart factory model, this factory is highly representative. Carbon trading market direction is influenced by a number of factors. The asymmetry of information is one of them. Market transparency and improvement require overcoming information asymmetry. In order to ensure the maximum transparency and openness of market information, corporate emissions data and distribution results must be made publicly available. It is imperative that this information participate actively, effectively, and interactively in the carbon trading market in order to remain sustainable and healthy over the long term. To achieve "carbon neutrality," markets operate according to fairness, justice, and transparency principles, as is the carbon trading market.

Path 2: An innovative approach

Innovation in management, standardized technologies, and standardized technology management are the three sub-paths. A business model innovation and an innovation in innovation. Digital technology actually drives precise management innovation. Energy industry "carbon management" aims to achieve "carbon neutrality", primarily through precise energy production efficiency management, and the reason for this high degree of "precise" management is because their goal is to maximize efficiency. To produce, transmit, store, and use energy in a decent manner, digital technology must be integrated with energy technology. .Through the use of digital innovation technology for the precise management model enables full-link energy interconnection and digitization of energy production on the network. In the energy industry, we are accelerating the construction of "carbon neutrality" by improving the efficiency of "carbon" consumption, and reducing CO2 emissions as a result. Furthermore, "mechanism innovation" should be further deepened at the level of "carbon neutrality" standardization. We will create a standard financing credit enhancement system as well as a "carbon neutral" standard innovative energy system. As part of achieving "carbon neutrality", energy sectors are encouraged to link technology, patents, and standards in a three-dimensional system.To improve management levels, energy firms must also innovate on the demand side in order to transition to "carbon neutrality." In order to follow this path, energy firms must develop resources on the demand side. Energy companies must cultivate demand-side business models and innovative market entities that can contribute to a "carbon-neutral" transition and development.

Path 3: A digital revolution

Since carbon neutrality has been proposed and proven to be feasible and effective in practice, The low-carbon economy and the digital economy have organically converged and are deeply integrated. By using big data, energy measure and the industry as a whole can use digital detection and management of carbon emissions to achieve “carbon neutrality”, which is driving the transition to “carbon neutrality” for the energy industry. In order to transition to a carbon-neutral future, the energy industry must accelerate the deployment of energy digitalization and an "intelligent energy network". Digitalization can also enable green technology innovation and entrepreneurship at the level of the Internet and artificial intelligence, as well as in the sector of digital finance for developing green finance and carbon finance innovations. A dynamic process is actually involved in digitalization's evolution and interaction. Carbon neutral transitions in the energy industry complement and promote carbon neutral transitions in the digital economy. As a result of digitalization, technological innovation has driven "carbon neutral" transitions and green development with a great deal of momentum. By developing digital technology innovations, the traditional energy industry is changing from a low efficiency to a high efficiency. Furthermore, carbon neutrality is a macro guideline for the future economic and social development of industrial energy based on innovation. As a result, digitalization is driven by relevant digital companies exploring how to collaborate and innovate digitally with energy counterparts in a “carbon neutral” manner, and on this basis, developing transition production plans for targeted energy firms based on this information. In order to reach "carbon neutrality" through the digitalization effect, enterprises, governments, and citizens must work together in a benign manner. Macro policymakers can play an major role in guiding companies and publics to make the transition from carbon neutrality to carbon neutrality. Secondly, macro policy makers can utilize capital to create a "leverage" effect. A national "carbon neutral" strategy is a long-term, firm strategy that micro energy companies should recognize urgently from their perspective. By promoting the "carbon neutral" transition, there is pressure for emissions to be reduced, but also great opportunities for its development. As a result of digitalization, the energy industry needs to actively respond to macro-policy demands to achieve a “carbon neutral” transition, by using digital technology to enhance efficiency in energy production, by achieving high-quality development, and by fulfilling environmental responsibilities.

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