Original Research Article

"Research on energy audit under the background of 'carbon peaking and carbon neutrality'"

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Abstract: Reducing greenhouse gas emissions and slowing down global warming has become a topic of common concern globally. Guiding the comprehensive low-carbon transformation of the economy and society and improving energy utilization efficiency has become an important issue. This paper provides a relatively detailed introduction and analysis of the institutional evolution, target positioning, and main components of energy audit under the background of "carbon peaking and carbon neutrality". The research in this paper has certain reference value for a deeper understanding of energy audit and promoting the improvement of the carbon neutrality institutional system.

Keywords: Climate change; Carbon neutrality; Energy audit

1. The necessity of energy audit

In recent years, extreme weather has occurred frequently, and climate issues have attracted much attention. In September 2020, China clearly put forward the "dual carbon" goals of carbon peaking in 2030 and carbon neutrality in 2060. Reversing the development model of high energy consumption and high emissions, guiding the comprehensive low-carbon transformation of the economy and society, and improving energy utilization efficiency have become important issues that need to be urgently addressed. Centering on the "dual carbon" goals, China has issued a series of top-level systems. On March 8, 2023, the National Development and Reform Commission issued the "Notice on Further Strengthening the Updating, Upgrading and Application of Energy Conservation Standards". The "Notice" pointed out that "the formulation and revision of energy audit standards should be actively promoted". On May 11, 2024, the "Notice on In-depth Energy Efficiency Diagnosis of Key Energy-consuming Units" issued by the National Development and Reform Commission once again emphasized that energy efficiency diagnosis of key energy-consuming units should be carried out and clearly defined four diagnosis methods: energy utilization status reports, energy conservation supervision and law enforcement, third-party energy audit and diagnosis services, and online monitoring of energy consumption.

Energy plays an important role in fields such as economic growth, social stability, and ecological security (Chen Shiyi and Qi Yu, 2022; Xu Zhiyao et al., 2023). Since 2006, the National Development and Reform Commission has required nine key industries to compulsorily carry out energy audit work in two ways. Energy audit has become an independent audit paradigm. By quantitatively detecting and evaluating the energy consumption of the audited object, it helps enterprises understand their own energy consumption situation and discover problems in energy management. The implementation of energy audit is conducive to promoting energy conservation and consumption reduction of the audited object and reducing production, operation and management costs (Ding Hongyan et al., 2022). The "General Technical Rules for Energy Audit" implemented in 2019 established the basic framework and norms for the promotion of energy audit.

2. Theoretical analysis of energy audit under the background of "carbon peaking and carbon neutrality"

"Carbon peaking and carbon neutrality" goals and energy audit China has issued a series of relevant documents, which have guaranteed and promoted the implementation and development of energy audit.The evolution of China's energy audit system is shown in Table 1.

Table 1. Evolution of energy audit system.

Time	Release documents	Policy release unit	Specific provisions of the document
In 1997,	Measures for the Administration of Energy Conservation in Key Energy-using Units and General Rules for Energy Audit Technology of Enterprises	The State Economic and Trade Commission of the People's Republic of China	Definition, content, method, procedure and report of enterprise energy audit
In 2006,	Notice on Printing and Distributing Enterprise Energy Audit Report and Audit Guidelines for Energy Conservation Planning	The National Development and Reform Commission	In 2007,1,008 key energy audits were conducted on key energy-using units in nine industries designated during the 11th Five-Year Plan period, laying a foundation for the formulation of energy conservation management policies for key energy-using enterprises
In 2008,	Regulations on Energy Conservation of Key Energy-using Enterprises	The National Development and Reform Commission	This regulation is the first specialized administrative regulation for the standardization of the energy-conservation work of the key energy-using enterprises since the founding of the People's Republic of China, and for the first time standardizes and institutionalize the energy-conservation work of the key energy-using enterprises
In 2017,	Comprehensive Work Plan for Energy Conservation and Emission Reduction during the 13th Five-Year Plan Period	State Department	We will strengthen energy consumption control in high-energy-intensive industries, fully implement energy efficiency benchmarking in key energy-consuming industries, promote the development of energy control centers for industrial enterprises, and promote intelligent monitoring and diagnosis technologies for industrial energy use.
In 2018,	Measures for the Administration of Energy Conservation in Key Energy-Using Units	The National Development and Reform Commission, the Ministry of Science and Technology and other seven ministries and commissions jointly revised and issued	It is emphasized that the administrative departments of the people's governments at or above the county level shall examine and verify the energy audit reports of key energy-using units, strengthen the daily management of energy conservation, and organize and implement the internal energy audit of their own units
In 2019,	The General Principles of Enterprise Energy Auditing Technology	Standardization Administration of China and General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China	From the technical level, the energy audit report is required to include four parts: basic information, energy audit content, energy-saving measures and suggestions, conclusions and suggestions
In 2022,	Comprehensive Work Plan for Energy Conservation and Emission Reduction during the 14th Five-Year Plan Period	State Department	We will improve the energy conservation monitoring system at the provincial, municipal, and county levels, and strengthen its monitoring capacity. Key energy-using units shall set up energy management posts and persons in charge as required.

Table 1. *(continued)*

Time	Release documents	Policy release unit	Specific provisions of the document
In 2023,	Notice on Further Strengthening the Update, Upgrading and Application and Implementation of Energy Saving Standards	The National Development and Reform Commission and the State Administration for Market Regulation	We will improve the development of supporting systems for energy conservation standards, and promote the formulation and revision of standards in measurement and testing, certification, analysis and calculation, energy efficiency evaluation, energy system optimization, equipment operation management, energy management system, energy performance evaluation, energy audit, energy conservation supervision, energy conservation review, and energy conservation services.
In 2024,	Notice on The In-depth Development of Energy Efficiency Diagnosis of Key Energy-Using Units	The National Development and Reform Commission	We will encourage regions where conditions permit to coordinate existing funding channels, and increase support for third-party energy audits and energy efficiency diagnosis in key energy-using units.

Energy audit clearly understands the usage of different types of energy, the distribution of energy consumption, and the associated carbon emissions by systematically collecting and analyzing energy consumption data (Liu Guochang, 1999), providing a basis for further determining the emission reduction potential of the audit object and formulating carbon emission reduction strategies. Energy audit can not only reveal the overall energy consumption situation but also identify bottlenecks and inefficient links in the energy management system. Through in-depth analysis of energy processes, equipment efficiency, and operation methods, specific links with energy waste and inefficient utilization can be identified, and targeted improvement suggestions can be put forward.

Based on the results of energy audit, specific carbon emission reduction suggestions and implementation measures can be formulated, including improving equipment efficiency, promoting energy-saving measures, upgrading equipment, adopting environmentally friendly equipment, and adopting clean energy (Baig et al., 2024). For example, for high-energy-consuming equipment, measures such as updating equipment, improving operation methods, and strengthening maintenance can be proposed to reduce energy consumption and carbon emissions (Adino et al., 2024). At the same time, the adoption of renewable energy sources such as solar and wind energy can be promoted to replace the use of fossil fuels and further reduce carbon emissions (Bigiotti et al., 2024).

Energy audit can also continuously monitor and evaluate emission reduction effects during the implementation process. Through the establishment of an effective monitoring system and data collection mechanism, energy audit can track energy consumption and emission reduction effects in real time, discover problems in time and adjust strategies.

2.1. Target positioning of energy audit

The primary goal of energy audit is to identify and evaluate the efficiency of enterprises or other energy-consuming units in energy utilization through comprehensive and systematic review and analysis, including the review of enterprise energy systems, energy facilities, and energy utilization processes, find out the links and reasons for energy waste, and put forward targeted improvement measures to improve enterprise energy utilization efficiency. Through energy audit, enterprises can more accurately understand their own energy consumption status, find out the bottlenecks and loopholes in energy consumption, and thus formulate effective energy-saving measures (Zhang Jianguo et al., 2013). For different subjects, energy audit has different goals: For

government departments, as a supervision and guarantee link, relevant laws and regulations need to be introduced in a timely manner and strictly implemented to promote the effective conduct of energy audit and improve the regulatory level of energy management; For enterprises and other relevant energy-consuming units, a reasonable internal control system needs to be set up to ensure a perfect energy management channel, cooperate with energy management activities such as energy audit carried out by relevant government departments, comply with and implement the requirements of energy-related laws and regulations, improve energy utilization efficiency through carrying out energy audit, timely discover and improve daily business activities that are not conducive to energy conservation and environmental protection, and at the same time ensure and improve their own profitability.

Energy audit not only focuses on the economic benefits of the audit object but also pays attention to environmental and social benefits. Through energy audit, enterprises can more deeply understand their own impact on the environment in terms of energy utilization, and thus formulate energy strategies and plans that meet the requirements of sustainable development, including reducing pollution emissions, improving resource utilization efficiency, promoting the application of green energy, etc., to achieve harmonious coexistence between the audit object and the environment and help the audit object achieve sustainable development. Therefore, energy audit can help the audit object understand and comply with relevant policy and regulatory requirements, avoid legal risks and economic losses due to illegal operations, and is also an important way for the audit object to fulfill social responsibilities and establish a good image.

3. Main content of the energy audit

3.1. Audit Subject

The audit subject of energy audit can vary in definition and practice according to different circumstances and needs. When choosing an audit subject, factors such as audit independence, audit quality, and audit cost need to be taken into consideration to ensure the efficiency and effectiveness of energy audit. At different levels, the subjects of energy audit are different.

a) At the macro level, the main body of energy audit is the national audit institution. As the main promoter of achieving the carbon neutrality goal, government audit institutions are also promoters of carrying out energy audit work. They have the right and obligation to supervise and manage the energy use activities of audit objects. Since energy audit is a powerful tool for supervising the energy use activities of audit objects, and government audit institutions are the main drivers, they should be the subject of energy audit.

b) At the micro level, the main subject of energy audit should be the internal audit department of energy-consuming units. In order to better abide by and implement relevant laws and regulations and fulfill corresponding social responsibilities, energy-consuming units should have initiative in energy management, actively improve energy use behaviors. The internal audit department should take the lead in checking, supervising, and improving the energy consumption links of enterprises. As the leading department, the internal audit department should be the subject of energy audit.

c) If an enterprise does not have an internal audit department or if the internal audit department does not have sufficient capacity and manpower to lead the energy audit, the energy-consuming unit can entrust social audits, such as accounting firms and technology suppliers, for assistance.

In addition, it should be noted that energy audit involves many disciplines. Different from financial audit, energy audit requires the participation of talents with professional knowledge in disciplines such as electricity,

computer science, and energy. At present, financial audit teams may still have deficiencies when conducting energy audits. At this stage, when carrying out energy audits, the power of technology suppliers can be borrowed. Through their provision of advanced energy monitoring and data analysis technologies, they can help the audit subjects carry out energy audit work.

3.2. Audit object

Energy audit is an activity that audits the physical and economic processes of energy use of energy-consuming units. The audit object of energy audit is the specific object targeted by the audit behavior.

a) Industrial and commercial organizations. Industrial and commercial organizations are one of the main objects of energy audit. Industrial and commercial organizations usually have large consumption of energy such as electricity, gas, and fuel. Through energy audit, it can help the audit object understand its own energy consumption structure and take corresponding measures to improve energy utilization efficiency and reduce carbon emissions.

b) Public institutions and government departments. Public institutions and government departments are also important objects of energy audit. Public institutions and government departments usually have a large number of public buildings, facilities and transportation systems, and the scale of energy consumption is large. Through energy audit, the energy utilization of public facilities can be optimized and energy waste can be reduced.

c) Communities and residential areas. Communities and residential areas are also one of the objects of energy audit. Through the audit of energy consumption in communities and residential areas, energy waste and inefficiency phenomena existing in residents' lives and community operations can be revealed, and corresponding improvement measures can be proposed to promote residents to take actions to save energy and reduce emissions and achieve sustainable development.

d) Specific industries and fields. Some specific industries and fields are also the objects of energy audit, such as energy production, manufacturing, construction, transportation, etc. These specific industries and fields usually have unique and obvious energy consumption characteristics. Through carrying out energy audit, formulate targeted policies for improving the "dual carbon" goal and implement corresponding emission reduction strategies and measures.

e) Macro regions. A specific macro region can also become the object of energy audit. Energy audit can be an important tool for national energy management and emission reduction policies. Through auditing the regional energy consumption structure and carbon emission situation, corresponding energy policies and emission reduction targets can be formulated to promote the country to achieve sustainable development and the "dual carbon" goal.

3.3. Audit method

The energy audit process mainly includes: preliminary communication, formulating work plans, kick-off meetings, collecting data, formulating test plans, on-site investigations and tests, analysis and evaluation, preparing reports, and summary meetings. In the process of implementing the energy audit process, energy audits mostly adopt the basic methods of financial audits, such as inspecting the relevant internal control setting documents and charters related to energy use of energy-consuming units, and inspecting the equipment and systems inside buildings, including heating, ventilation, air conditioning systems, lighting equipment, etc. Check the operating efficiency of the equipment, whether there are problems such as air leakage and electric leakage,

and evaluate the aging degree and maintenance status of the equipment.

However, energy audit also has its own characteristics. For example, through on-site investigations and data collection, obtain energy usage data of buildings, facilities and equipment, including the consumption of electricity, natural gas, water, etc.; investigate the operating status of on-site equipment and systems, and record the patterns and characteristics of energy consumption. Analyze the collected energy data to identify the main sources and trends of energy consumption; use statistical methods and modeling techniques to analyze the seasonal changes and peak-valley loads of energy use, and find out the direction of optimizing energy utilization; use energy simulation software to simulate and optimize the energy consumption of buildings and equipment. By adjusting parameters and improving design schemes, evaluate the impact of different improvement measures on energy consumption and find the optimal scheme; evaluate the design and operation of the energy management system, including monitoring systems, metering systems, etc. Check the data acquisition and analysis capabilities of the system and evaluate the actual effect of the system in energy conservation and emission reduction.

3.4. Audit contents

The content of energy audit covers aspects such as an overview of energy management, energy consumption, and energy utilization efficiency. The audit results can provide valuable references for the audit object, helping the audit object formulate and implement targeted energy-saving strategies, reduce energy waste, and lower operating costs. In the process of energy audit, there are two audit contents that need to be focused on.

First, ensuring compliance with basic audit procedures is crucial, which means conducting exhaustive inspections and consultations. This not only involves understanding the internal institutional setup of energy-consuming units but also includes grasping the internal economic responsibility system and its specific implementation. Through in-depth understanding, it can help the audit subject comprehensively grasp the management status of energy-consuming units, including their institutional setup, personnel allocation, function division, system implementation, index setting, etc., laying a solid foundation for the conduct of energy audit.

Second, it is extremely important to have a detailed grasp of the energy consumption measurement and statistical data of the audit object. The audit team should include members proficient in energy measurement-related majors. Based on the real-time data of the energy consumption online monitoring system of energy-consuming units, they can more accurately judge the accuracy of measuring instruments and the authenticity of statistical data. Comprehensive evaluation can ensure the accuracy and reliability of energy audit results and provide more valuable feedback and suggestions for energy-consuming units.

3.5. Audit basis

The “General Rules for Energy Audit” is the latest energy audit guideline launched in China. It takes the “General Technical Rules for Energy Audit” as the fundamental compliance and also follows the following principles:

a) The content of the audit should be consistent with the determined goals, scopes, and boundarie.

b) The audit process should meet the requirements of relevant standards and specifications.

c) The selected relevant variables should be representative.

d) The data used in the audit should be true and accurate.

e) The process of data collection, verification, and analysis should be traceable.

f) Energy-saving measure suggestions should be based on reasonable technical and economic analyses.

3.6. Audit conclusions

As an important tool for evaluating energy use efficiency and identifying energy-saving potential, the results of energy audit can provide valuable insights and action directions. Generally speaking, energy audit should reveal the optimization space of the audit object in energy management and use. The audit conclusion should highlight the importance of strengthening energy monitoring and management and promoting energy-saving technologies and equipment, such as how to reduce energy costs and improve equipment utilization.

4. Tag

In the process of "carbon peaking and carbon neutrality", energy conservation and emission reduction has become an important issue, and the importance of energy audit is IVparticularly prominent. Energy audit is conducive to strengthening energy management, transforming energy-saving management into standardization and scientification, and promoting sustainable economic development. Actively carrying out energy audit plays a key role in energy conservation and emission reduction. This article provides a relatively detailed introduction and analysis of the institutional evolution, target positioning, and main components of energy audit under the background of "carbon peaking and carbon neutrality", which has certain reference value for the promotion and implementation of energy audit.

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