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Measures and Practices for Energy Saving and Emission Reduction in Oil Depot Stations under the "Dual Carbon" Goals

Man Ruan [1, a], Jinmao Chen [1, b], Jianli Zhao [1, c], Wanli Xu [1, d], Youjie Zhou [1, e], Long Huang [1, f], Yujuan Yin [1, g], Mengyi Wang [1, h], Peiqiang Chen [1,2, i], Xudong Wang [1, j] *

[1] Institute of System Engineering Academy of Military Science, Beijing, 102300, China;

[2] School of Power and Energy Engineering, Harbin Engineering University, Harbin, 150001, China.

[a] Newenergyrm@163.com, [b] energycjm@163.com, [c] 2426176008@qq.com,

[d] energywxd@163.com, [e] zhoujie_76@126.com, [f] hlong0000@163.com, [g] yinyj2025@163.com,

[h] wmyncut@163.com, [i] chenpeiqiang@hrbeu.edu.cn, [j] energywxd@163.com

Abstract. Energy conservation and consumption reduction are vital for alleviating energy constraints and advancing ecological civilization. Within energy management, improving efficiency at oil depot stations represents a critical scenario and leverage point for achieving broader energy-saving and emission-reduction targets. These stations bear significant responsibility for enabling green development and pioneering energy efficiency. This paper examines the context of China's "Dual Carbon" (Carbon Peaking and Carbon Neutrality) goals. It begins by analyzing the current energy consumption patterns and carbon emission structures of oil depot stations, highlighting their substantial potential for improvement. Subsequently, from three perspectives—energy substitution, energy-saving technology upgrades, and oil vapor recovery and emission reduction—it systematically explores the application of renewable energy sources (e.g., photovoltaic, wind, geothermal) and the principles, benefits, and implementation strategies of key technologies like variable frequency drives and waste heat recovery. The paper also provides an in-depth analysis of optimization paths and intelligent development trends for oil vapor recovery technologies. Finally, based on identified trends such as intelligentization and integration, it proposes specific recommendations targeting policy environments and corporate practices. The aim is to offer theoretical reference and practical guidance for oil depot stations and related energy enterprises in formulating scientific, viable pathways for energy saving, emission reduction, and sustainable green development.

Keywords: Oil Depot Station; "Dual Carbon" Goals; Energy Saving and Emission Reduction; Recommended Measures

1. Introduction

Global climate change poses a common challenge for humanity, making the transition to a green, low-carbon energy system an international consensus. As the world's largest energy producer and consumer, China's "Carbon Peaking and Carbon Neutrality" goals [1, 2] represent not only a solemn commitment to global climate action but also an inherent necessity for optimizing its domestic economic structure and achieving high-quality development [3]. This macro context imposes profound transformation pressures across the entire energy industry chain. As critical nodes connecting upstream production with downstream consumption, oil depot stations face particularly urgent and important imperatives to green and decarbonize their operational models.

Oil depot stations play an indispensable role in ensuring national energy security and market stability. However, their operations—involving the storage, transfer, and processing of oil products—generate significant direct and indirect carbon emissions, as well as pollutants like Volatile Organic Compounds (VOCs). Traditional extensive management models are increasingly inadequate to meet the new requirements under the "Dual Carbon" goals. While existing research has addressed specific energy-saving technologies applicable to oil depot stations [4, 5], a systematic framework integrating energy substitution, energy efficiency improvement, and

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end-of-pipe treatment to guide the holistic low-carbon transformation of these facilities is still lacking. Furthermore, future trends towards intelligent operation and the requisite policy and market environments warrant proactive exploration.

Therefore, this study aims to systematically review the energy consumption and emission profiles of oil depot stations, analyze practical technological pathways for energy saving and emission reduction, and delve into their future development trends and implementation routes. The findings are intended to provide direct theoretical support and practical guidance for oil depot station enterprises formulating scientific carbon reduction strategies, serve as a reference for policymakers designing effective incentives and regulatory mechanisms, and offer valuable insights for the global green transformation of traditional energy infrastructure.

2. Energy Consumption Status and Carbon Emission Analysis of Oil Depot Stations

2.1 Research Status on Energy Consumption in Oil Depot Stations

The section headings are in boldface capital and lowercase letters. Second level headings are typed as part of the succeeding paragraph (like the subsection heading of this paragraph). All manuscripts must be in English, also the table and figure texts, otherwise ${}_{s}w$ we cannot publish your paper. Please keep a second copy of your manuscript in your offic

Li Xuemin et al. noted that oilfield production operations are both major energy producers and consumers. The oil transportation system is a primary component of oilfield surface engineering and a main energy consumption unit. Implementing energy saving and consumption reduction benefits production, conserves substantial energy, and promotes the sustainable development of oilfields. Therefore, enhancing oil transportation system efficiency, saving energy, reducing consumption, and optimizing the surface system are key research directions in surface engineering [6].

Liu Xia et al. identified pumps (water blending pumps, oil transfer pumps, hot washing pumps) and furnaces (water blending/hot washing furnaces, heating furnaces) as the main energy-consuming equipment in oil transportation systems, primarily using electricity and natural gas. Improving the operational efficiency of the oil transportation system and reducing various specific consumptions can be achieved through system optimization, electricity saving, and gas saving. This includes system optimization adjustments at transfer stations and simplifying surface processes to enhance overall operational efficiency. Specific measures include: replacing inefficient pumps with high-efficiency pumps to reduce transportation-specific consumption; using smaller pumps instead of oversized pumps to lower electricity consumption; utilizing variable frequency drive devices to improve the efficiency of the external oil transportation system; and installing energy-saving burners to conserve natural gas [7].

The entire oil depot system is an interconnected, multi-level system composed of unit equipment with different functions assembled physically in a hierarchical manner [8]. Each unit equipment is the smallest energy-using entity, and analyzing the nature of energy use is fundamental to constructing a system energy balance. As shown in Table 1, energy consumption can be divided into four parts: The first part is consumed by oil transfer pumps, converting electrical energy into the pressure energy of crude oil flow (input: electricity, output: pressure energy). The second part involves heating furnaces, heat exchangers, and boilers, related to the utilization rate of thermal energy. The third part comprises energy lost to overcoming frictional resistance and throttling losses within the oil pipelines. The fourth part accounts for changes in tank inventory energy due to differences between inflow and outflow volumes during the measurement period.

Table 1. Three Scheme comparing

Name	Description	Energy Use Unit
Oil Transfer Pump	Provides pressure energy for external oil product transfer	Energy Conversion

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Heating Furnace	Heats external crude oil	Energy Conversion
Heat Exchanger	Provides heat to crude oil via high-temperature medium	Energy Utilization
Boiler	Provides heat for storage tanks and work areas	Energy Conversion
Oil Pipeline	Conveys crude oil	Energy Transmission
Oil Tank	Stores oil products	Energy Utilization

2.2 Analysis of Energy Saving and Emission Reduction Potential

As critical nodes for energy storage and distribution, oil depot stations account for a considerable proportion of energy consumption and carbon emissions. A thorough analysis from the technical, managerial, policy, and market dimensions reveals that oil depot stations possess significant potential for energy conservation and emission reduction, which is of great importance for promoting green development within the industry.

On the technical front, efforts should focus on optimizing storage technologies, improving loading/unloading and transportation technologies, and enhancing energy recovery and utilization technologies. In traditional oil storage processes, product volatilization leads to energy loss and environmental pollution. Adopting advanced sealed storage technologies, such as internal floating roof tanks, can effectively reduce oil volatilization. During loading and unloading operations, the use of closed loading/unloading systems prevents oil leakage and volatilization. Concurrently, employing high-efficiency pumps and pipeline systems enhances oil transportation efficiency and reduces energy consumption. Oil depot stations generate substantial amounts of waste heat during operation, such as flue gas waste heat from boilers and condensation heat from refrigeration equipment. By installing waste heat recovery devices, this waste heat can be captured and reused for heating, space heating, or power generation, thereby improving the overall energy utilization rate.

On the management front, it is essential to establish energy management systems, enhance equipment maintenance and management, and strengthen personnel training and management. A comprehensive energy management system should be implemented to enable complete monitoring, analysis, and control of energy consumption at oil depot stations. By setting energy consumption quotas and performance indicators, energy management targets can be broken down and assigned to various departments and positions, clarifying responsibilities and fostering a company-wide energy management framework. Strengthening the routine maintenance and upkeep of equipment ensures optimal operational status, reducing energy waste caused by equipment failures. Intensifying training for employees on energy conservation and emission reduction raises their awareness and improves their operational skills.

On the policy front, governments should introduce stringent environmental regulations and standards to impose strict limits on pollutant emissions from oil depot stations. Through financial subsidies and tax incentive policies, governments can encourage oil depot stations to adopt energy-saving and emission-reduction technologies and equipment. Establishing a carbon emission trading market that incorporates the carbon emissions of oil depot stations is also crucial.

On the market front, with growing societal environmental awareness, consumer demand for green energy and eco-friendly products continues to increase. As a vital link in the energy supply chain, oil depot stations that provide green and clean energy products and services can meet this consumer demand and enhance their market competitiveness. Within the energy supply chain, upstream and downstream enterprises are imposing increasingly higher environmental requirements on oil depot stations. In the intensely competitive market, oil depot stations that achieve notable results in energy conservation and emission reduction can lower their operating costs, improve product quality and service levels, thereby securing a dominant market position.

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3. Energy Saving and Emission Reduction Measures for Oil Depot Stations Under the Dual Carbon Goals

3.1 Energy Substitution Technology

3.1.1 Application of Photovoltaics in Oil Depot Stations

As end-use energy consumers, oil depot stations can directly reduce their reliance on thermal power by applying photovoltaic (PV) power generation technology, thereby supporting the "dual carbon" goals [9]. The specific benefits are reflected in: reducing carbon emissions and pollutant emissions; reducing noise and resource consumption; and enhancing energy system resilience. For instance, in the event of a grid power outage caused by extreme weather, a "PV + energy storage" system can serve as an emergency power source, ensuring the continuous operation of key depot equipment and reducing safety risks.

Photovoltaic power generation is a technology that converts light energy directly into electricity using the photovoltaic effect at semiconductor interfaces. The core of PV power generation is the photovoltaic effect.When semiconductor materials absorb photons from sunlight, internal electrons gain energy, break free from atomic bonds, forming free electrons and electron holes (electron vacancies). These then move directionally under the influence of an internal electric field within the semiconductor, thereby generating a direct current (DC).

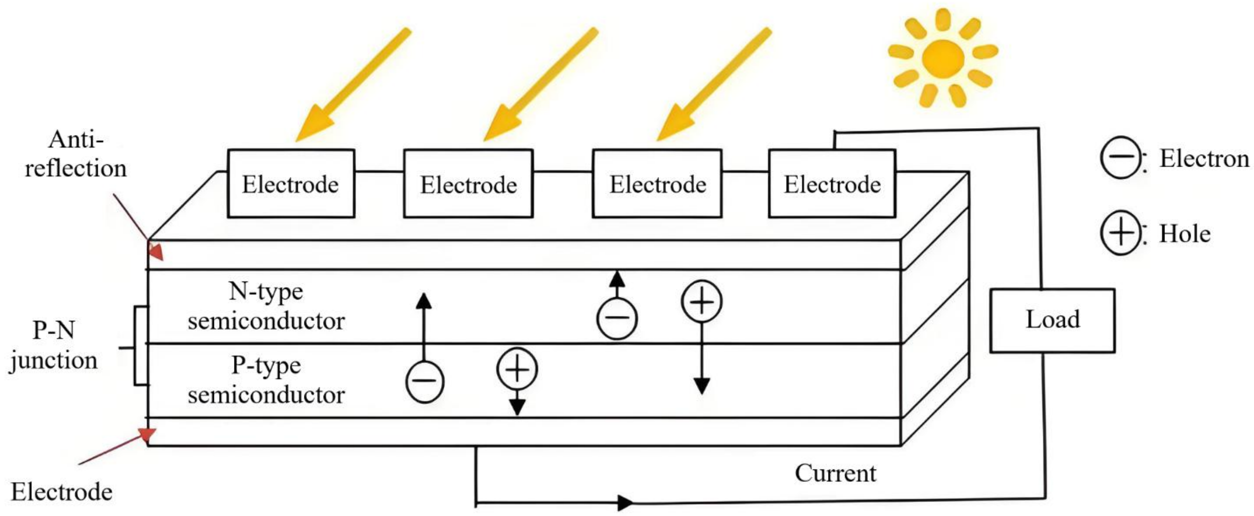

Fig. 1 Schematic Diagram of Photovoltaic Power Generation

A typical application scenario involves building-mounted rooftops, such as installing distributed PV systems on the roofs of oil depot station buildings and canopies, or constructing PV carports. When integrating PV systems, oil depot stations can consider power facilities such as the PV generation system itself, energy storage systems, and charging piles. As oil depot stations are classified as flammable and explosive hazardous locations, their PV systems must prioritize safety design (e.g., explosion-proof, lightning protection, and fire prevention) while meeting power generation efficiency requirements.

3.1.2 Application of Wind Energy in Oil Depot Stations

Driven by the "dual carbon" goals, the energy supply for oil depot stations is transitioning from a model reliant solely on the external power grid and fossil fuels towards a cleaner, low-carbon model characterized by "multi-energy complementarity and comprehensive utilization." Beyond the already widely applied PV technology, wind and geothermal energy, as important localized renewable sources, also possess considerable application potential in specific scenarios. They can effectively complement PV, further enhancing the energy self-sufficiency rate and green credentials of oil depot stations.

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The core advantage of wind power generation lies in its natural temporal complementarity with PV generation. Periods of strong sunlight during the daytime typically coincide with peak PV output, whereas wind resources are often more abundant during nighttime, winter, or cloudy/rainy weather. Within the context of oil depot stations, the potential for wind energy is significant. Constructing "wind-PV complementary" systems can, to some extent, smooth the total output curve of renewable energy, reduce the required capacity of energy storage systems, and provide a more stable supply of green electricity. Wind turbines (especially small-scale ones) have a relatively small ground footprint and can be integrated within the depot's green belts, boundary areas, etc., making effective use of otherwise unused space. For oil depot stations located in remote areas or with weak grid connections, distributed wind energy can serve as a reliable backup power source, enhancing energy security.

The application of wind energy in oil depot stations is not universally suitable; its successful implementation depends heavily on specific site conditions. The location of the depot should be in an area characterized by high annual average wind speed and high wind power density. Strict adherence to safety distances is mandatory. The installation location of wind turbines must be situated at a safe distance from explosion hazard areas such as tank farms and loading/unloading areas, ensuring sufficient fire and explosion prevention spacing. They should generally be placed within the depot's safety buffer zone or peripheral areas. Turbulence effects must be considered. Tall storage tanks and building clusters can create complex airflow patterns, affecting turbine efficiency and lifespan; therefore, professional micro-siting assessment is required.

3.1.3 Application of Geothermal Energy in Oil Depot Stations

Unlike the power generation attributes of wind and PV energy, the application of geothermal energy in oil depot stations primarily focuses on the domains of heating, cooling, and process heating. It is a key technology for achieving thermal energy substitution and reducing natural gas consumption. Ground-source heat pump systems boast significantly higher energy efficiency compared to traditional gas boilers and electric compression chillers, resulting in substantial energy savings. Furthermore, they are stable and reliable, unaffected by weather conditions. The temperature of shallow underground soil remains relatively constant throughout the year, enabling stable operation of ground-source heat pump systems unaffected by diurnal, seasonal, or weather changes, thereby providing a consistent and reliable source of heating and cooling. By directly replacing gas boilers used for space heating and domestic hot water preparation with geothermal energy, natural gas consumption and its associated carbon emissions can be reduced at the source.

The feasibility of geothermal application depends primarily on geological conditions and energy demand. The depot site should possess suitable thermal properties, such as good soil thermal conductivity and moderate groundwater levels. Sufficient underground space for burying the ground loop heat exchanger is necessary. This can be achieved by utilizing areas like the depot's green spaces, beneath parking lots, or along roadsides to install vertical boreholes or horizontal slinky ground loops. For sites with particularly limited space or unsuitable geological conditions for drilling, utilizing nearby water bodies with water-source heat pump systems can also be considered. Geothermal energy is ideally suited for meeting the heating and cooling demands of buildings within the oil depot station, such as office buildings, control rooms, and duty dormitories. Ground-source heat pump systems can be integrated as part of the oil depot station's comprehensive energy system, working in synergy with solar thermal systems and waste heat recovery systems to build an efficient, low-carbon, multi-energy complementary heating and cooling system.

3.2 Energy-Saving Technologies

3.2.1 Variable Frequency Drive Energy-Saving Technology for Oil Transfer Pumps

Oil transfer pumps play a critical role in storage depots, responsible for transporting crude oil from storage facilities to various destinations. To address the issues of energy waste and low efficiency during pump operation, Variable Frequency Drive (VFD) technology in pump systems

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has garnered widespread attention. By controlling the motor speed, the VFD can adjust the transfer speed according to actual demand, thereby reducing energy consumption. Additionally, it enables smooth starting and stopping, mitigating equipment wear and maintenance costs, and enhancing system reliability.

Variable frequency speed regulation is an energy-saving control technology that adjusts motor speed by changing the power supply frequency. Its core principle is "speed regulation on demand, precise load matching," making it a key method for saving energy during the equipment operation phase. The working principle is based on the proportional relationship between motor speed and supply frequency. The VFD converts mains frequency AC power into adjustable frequency AC power, achieving precise speed control. Its core components include a rectifier unit (AC to DC), an inverter unit (DC to variable frequency AC), and a control unit (adjusts frequency based on load signals). It is primarily suited for rotating machinery like fans, pumps, and compressors that operate under varying loads. Pairing VFDs with high-efficiency host equipment maximizes energy-saving effects.

The core energy-saving function of VFD technology is primarily manifested in significantly reducing energy consumption under variable loads. For fan and pump loads, energy consumption is proportional to the cube of the speed; thus, reducing speed when load decreases leads to substantial energy savings. It replaces traditional energy-wasting regulation methods, eliminating energy losses caused by throttle valves, dampers, etc., and allowing equipment to always operate within its high-efficiency range. Soft starting protects equipment by avoiding the high current surge during motor startup, reducing equipment wear and grid fluctuations, extending equipment service life, and indirectly lowering maintenance and replacement costs.

3.2.2 Waste Heat Recovery Technology

During the operation of oil depot stations, a significant amount of low- and medium-grade thermal energy is discarded into the environment through flue gas, steam condensate, and process medium cooling. This represents both a waste of energy and an contributor to thermal pollution. The core of waste heat recovery technology lies in effectively capturing this "waste heat" through a series of thermal equipment and reusing it in production processes or auxiliary systems, thereby achieving cascading utilization of energy and significantly reducing the consumption of primary energy (e.g., natural gas, purchased steam).

The main sources of waste heat in oil depot stations are multifaceted, including, for example, waste heat from boiler and furnace flue gas, cooling processes of process equipment, waste heat generated by compressor operation, and the sensible heat of steam condensate.Waste heat recovery can utilize heat exchangers, waste heat boilers, or heat pump technology. Heat exchangers are the most fundamental and widely used devices in waste heat recovery systems, responsible for transferring heat between two fluids without direct contact. When the waste heat source has a relatively high grade (e.g., flue gas above 400°C) and sufficient quantity, waste heat boilers can be employed to recover energy. Heat pump technology is highly effective for recovering low-grade waste heat (typically below 60°C), as it can "upgrade" low-temperature heat sources that are difficult to use directly to useful temperatures.

For oil depot stations, waste heat is not a burden but a valuable resource. By applying a combination of technologies like heat exchangers, waste heat boilers, and heat pumps to construct a multi-level, integrated waste heat recovery network, the scattered waste thermal energy can be reintegrated into the energy supply chain. This not only directly reduces the procurement costs of natural gas and electricity, enhancing the economic benefits of the enterprise, but also significantly cuts carbon emissions by reducing fossil fuel consumption. It represents a solid step for oil depot stations towards "smart, green, and efficient" operation.

3.3 Oil Vapor Recovery and Emission Reduction Technology

Oil vapor recovery technology reduces emissions, protects the environment, and improves energy efficiency by collecting, treating, and recovering oil vapors. Common oil vapor recovery

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methods currently include adsorption, absorption, condensation, and membrane separation [10]. Combining oil vapor recovery technologies is a current research focus, as hybrid methods can significantly mitigate the drawbacks of individual methods and leverage their respective advantages. In large-scale, high-concentration oil vapor emission scenarios like oil depots and refineries, adsorption and condensation methods are most widely used due to their high recovery rates [11]. Combined processes have become a development trend to balance efficiency and cost. For instance, a common combination is "adsorption + condensation," where the adsorption method first enriches low-concentration vapors into high-concentration vapors, followed by the condensation method liquefying and recovering them. This combination leverages the high efficiency of adsorption for treating low-concentration streams and the advantage of condensation in directly producing liquid product, thereby reducing overall energy consumption. The membrane method is often used as an auxiliary concentration unit in conjunction with condensation or adsorption. Modern advanced oil vapor recovery systems are equipped with Programmable Logic Controllers (PLCs) and online concentration monitors. These systems can automatically optimize operation (e.g., adjusting fan frequency, refrigeration power, desorption cycle) based on parameters like inlet vapor concentration and flow rate, achieving energy savings and stable, compliant operation.

Optimizing and upgrading existing oil vapor recovery systems is key to further unlocking emission reduction potential, lowering operating costs, and maximizing resource recovery.Technical Optimization: Adoption of New Adsorption Materials. The effectiveness of the adsorption method highly depends on the adsorbent material. While traditional activated carbon is widely used, it suffers from issues like competitive adsorption, performance degradation in humid and hot environments, insufficient mechanical strength leading to easy powdering. The development of new adsorbent materials is core to upgrades. Current research hotspots for adsorbents include high-performance activated carbon fiber, hydrophobic zeolite molecular sieves, and metal-organic frameworks (MOFs).System Intelligence Upgrade: Enhancing Automation Control Level. Upgrading oil vapor recovery systems from "fixed-program operation" to intelligent agents capable of "perception-decision-optimization" is crucial for achieving refined management and eliminating idle energy consumption. An intelligent control strategy can employ adaptive control based on real-time concentration. Online oil vapor concentration monitors (VOC detectors) are installed at the inlet and outlet of the unit. The control system automatically adjusts the VFD of the extraction fan based on real-time changes in the inlet concentration, controlling the treatment air volume according to the principle of "high air volume for high concentration, low air volume for low concentration," thereby preventing the fan from idling and consuming electricity under low load conditions.

4. Development Trends and Recommendations for Energy Saving and Emission Reduction in Oil Depot Stations under the Dual Carbon Goals

4.1 Development Trends

Guided by the "Dual Carbon" strategy, energy saving and emission reduction efforts in oil depot stations are evolving from localized, isolated technical retrofits towards a comprehensive, systematic, and profound transformation. The development trends can be summarized as: technology moving towards "Intelligent and Integrated" and systems advancing towards "Green and Efficient" [12]. Energy-saving and emission-reduction technologies are developing in the direction of intelligentization, automation, and integration. In the future, technology will no longer be merely a singular tool for saving energy but will become the "smart core" and "neural network" that empowers the overall optimization of oil depot stations.

Intelligentization is primarily manifested in the shift from "experience-driven" to "data and algorithm-driven" operations. Utilizing technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and digital twins enables precise perception, intelligent decision-making, and predictive maintenance.Automation is mainly reflected in the change from "manual

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intervention" to "unmanned operation and precise control". Automated equipment and systems reduce human operational errors, enhance execution efficiency, safety, and response speed.Integration is embodied in the transition from "single-point energy saving" to "system-wide energy efficiency". Future competition will hinge on system efficiency. Integration means treating various energy-saving technologies as an organic whole for synergistic optimization.

The oil depot stations of the future will shed their traditional image of high energy consumption and high emissions, undergoing the following three major transformations: becoming an intelligent node, transforming into a green hub, and upgrading into a highly efficient plant.

4.2 Policy Recommendations

To effectively promote the achievement of the "Dual Carbon" goals in oil depot stations, it is essential to establish a well-structured policy and market environment that combines incentives with constraints, while clearly defining the responsibilities of all parties to form a collaborative governance framework. This involves strengthening standard-setting and rigid constraints by formulating stricter energy efficiency standards and enhancing environmental emission standards. Furthermore, market mechanisms and economic policies should be improved by refining the carbon emission trading market and increasing financial subsidies and tax incentives. Innovations in green finance and market services are also crucial, including developing green financial products and ensuring the consumption of green electricity.

Achieving the "Dual Carbon" goals is a systematic project that requires the government, enterprises, and all sectors of society to clarify their respective roles and work together. At the government level, it is essential to play a leading role in providing guidance and supervision. At the enterprise level, the main responsibility should be fulfilled through active transformation and innovation. All sectors of society should contribute by exercising oversight, providing services, and fostering a favorable atmosphere. The key to promoting energy conservation and emission reduction in oil depot stations lies in establishing a multi-stakeholder governance system characterized by "government guidance, enterprise leadership, and social participation." By establishing strict regulations and standards to set the baseline, providing strong economic incentives to stimulate dynamism, optimizing resource allocation through sound market mechanisms, and ensuring implementation by clarifying the responsibilities of all parties, it becomes possible to pool all forces to jointly overcome challenges. This will ensure the smooth green and low-carbon transition of the oil depot station industry, contributing critical strength to the realization of the national "Dual Carbon" goals.

4.3 Corporate Practice Recommendations

Facing the "Dual Carbon" goals, oil depot station enterprises should view challenges as opportunities for transformation and upgrading. Through systematic internal practices, they can translate green and low-carbon concepts into core competitiveness. Enterprises need to base their actions on their actual situation, formulate scientific plans, and advance coordinately across three dimensions: technological innovation, management optimization, and personnel awareness [13, 14].

Enterprises should not work in isolation but actively embrace external resources, seizing development opportunities through technological innovation and cooperation to build a powerful engine for green transformation.Prioritize investment in "short-term, fast-result, high-return" projects; focus mid-term on energy structure optimization; and track cutting-edge technologies long-term. Establish joint laboratories with universities and research institutes to tackle depot-specific energy-saving and carbon-reduction challenges. Cooperate with excellent Energy Service Companies (ESCOs), adopting models like Energy Performance Contracting (EPC) to address high initial investment costs. Actively participate in industry associations to learn advanced technologies and practical experiences from peer benchmark enterprises, avoiding repetitive detours.

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Excellent management is the guarantee for maximizing the benefits of technology. Optimize energy management strategies to build the foundation for precise operations. Construct a Digital Energy Management System and implement full lifecycle equipment management. The best technologies and systems ultimately require people to implement them. Employee awareness and action are key to success.Enhance employee awareness of energy saving and emission reduction, and cultivate a culture of all staff participation. Regularly organize knowledge lectures, skill competitions, and accident drills to ensure frontline staff understand the energy consumption and safety implications behind every operation. Establish effective incentive and constraint mechanisms, set up special reward funds, and strengthen performance-oriented evaluation. Furthermore, enterprises must avoid a "one-size-fits-all" and "campaign-style" approach to emission reduction. They should, based on their own circumstances, formulate scientific and reasonable implementation paths and advance steadily.

The green and low-carbon transformation of oil depot station enterprises is a marathon requiring the parallel drive of the "troika" of technology, management, and culture. By enhancing hard power through strengthened innovation and cooperation, boosting soft power through optimized management strategies, and supplementing with the cohesive force of a culture of all staff participation, combined with a tailored, scientific, and robust implementation path, enterprises can navigate the "Dual Carbon" wave steadily and for the long term, achieving a win-win for both environmental and economic benefits.

5. Conclusion

This paper has systematically explored the challenges and opportunities faced by oil depot stations under the "Dual Carbon" goals and proposed corresponding measures and practical pathways for energy saving and emission reduction. The main conclusions are as follows:

Firstly, oil depot stations, as high-energy-consumption nodes, possess significant potential for energy saving and emission reduction. Analysis of the energy consumption structure reveals that electricity and natural gas consumption are primarily concentrated in key equipment such as oil transfer pumps and heating furnaces, pinpointing the main direction for technological energy saving. Potential analysis from the four dimensions of technology, management, policy, and market indicates that oil depot stations have the capability to achieve substantial emission reductions through systematic optimization.

Secondly, achieving deep emission reductions relies on constructing a multi-level comprehensive technological system. Specifically: On the energy supply side, vigorously promote renewable energy sources like photovoltaic and wind power for energy substitution. On the energy consumption side, widely apply energy-saving technologies such as variable frequency speed regulation and waste heat recovery to enhance efficiency. On the process emission control side, advanced emission reduction technologies like oil vapor recovery must be adopted to curb unorganized emissions of pollutants and greenhouse gases. These three aspects complement each other, collectively forming the technological core for oil depot stations to achieve the "Dual Carbon" goals.

Finally, the green and low-carbon transformation of oil depot stations is a long-term and systematic project requiring top-level design and multi-party collaboration. Future development will exhibit distinct characteristics of intelligence and integration, leveraging digital technology to achieve a leap from single-point energy saving to system-wide energy efficiency. To this end: It is necessary for the government to create a favorable policy and market environment, driving transformation through standard guidance, economic incentives, and improved market mechanisms. It is also essential for enterprises to play the main role by formulating scientific plans, strengthening technological innovation, optimizing management systems, and fostering an energy-saving culture, thereby internalizing energy saving and emission reduction as their core competitiveness.

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In summary, only through the synergistic innovation of "Technology-Management-Policy" can oil depot stations successfully transition into intelligent, green, and efficient comprehensive energy hubs, contributing their due share to the national "Dual Carbon" strategic goals while serving national energy security.

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