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Study on the Impact of Hospital Energy-Saving Technologies on Energy Conservation, Cost Reduction, and Efficiency Improvement in High-Tech Enterprises

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Abstract: Against the backdrop of the dual carbon goals, energy-saving retrofitting has become a critical pathway for high-tech enterprises to reduce costs, fulfill carbon assessment requirements, and enhance competitiveness. Hospitals have long accumulated mature energy-saving technologies such as waste heat recovery, smart energy consumption control, and precision temperature regulation for clean spaces. The around-the-clock, stringent temperature control operating conditions of hospitals are highly compatible with the clean workshops and constant-temperature laboratories of enterprises. At the present stage, most enterprises still rely on conventional industrial energy-saving solutions and have yet to adopt medical energy-saving technologies, commonly suffering from problems such as extensive energy consumption management, waste heat loss, and excessive temperature control energy consumption. In light of this, this paper takes the mature energy-saving technology system of hospitals as the primary research subject, analyzes the application value of transferring such technologies to high-tech enterprises, sorts out the practical obstacles in the technology transfer process, and proposes targeted implementation strategies. Drawing on publicly available project measurement data, the paper quantifies the energy consumption reduction effects of retrofitting, with the aim of providing practical references for high-tech manufacturing industries to introduce medical energy-saving technologies, facilitating low-cost, low-carbon transitions, and achieving synergistic development between corporate economic benefits and regional carbon reduction targets.

Keywords: Hospital energy-saving technologies; High-tech enterprises; Energy conservation and cost reduction; Smart energy management and control

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1. Introduction

Policy documents such as the *Action Plan for Carbon Peaking During the 15th Five-Year Plan Period* have explicitly called for advancing energy conservation and carbon reduction in public institutions. These policies urge intensified efforts in energy-saving and carbon-reduction retrofitting, guide public institutions to prioritize the use of renewable energy, align energy and resource consumption indicators with relevant budgets, explore the implementation of graded energy efficiency and carbon emission levels for public institutions, and progressively enhance the digital and intelligent level of energy and carbon management [1]. Efforts are being made to comprehensively promote the development of conservation-minded government agencies, establish model conservation-oriented public institutions at high standards, and build low-carbon public institutions. Hospitals are required to maintain stable environmental indicators around the clock. Under the constraints of the Evaluation Standard for Green Hospital Building, they have continuously undergone energy-saving iterations over the years. Technologies such as HVAC, waste heat recovery, and intelligent energy control have been validated through years of around-the-clock operating conditions, and comprehensive energy-saving retrofits have enabled medical institutions to achieve energy consumption reductions of 18% to 30% [2]. The energy consumption demands of clean production spaces in high-tech enterprises are highly similar to those of operating rooms and inspection laboratories in tertiary hospitals. However, significant industry-specific technological barriers exist, and most manufacturing enterprises still rely on general-purpose industrial equipment for their energy-saving retrofits. Bridging the channel for the transfer and application of hospital energy-saving technologies to high-tech manufacturing enterprises, and unlocking the practical value of cross-industry energy-saving technologies, has become a pressing practical issue that must be addressed in the low-carbon transformation of advanced manufacturing industries.

2. Core value of hospital energy-saving technology applied to hightech enterprises

The hospital energysaving technology system, refined through longterm standardized practice, offers substantial practical value when transplanted into the production scenarios of hightech enterprises.

At the economic level, this technology has undergone prolonged operational optimization, resulting in low equipment failure rates and short payback periods. It avoids the problems of poor adaptability and rapid degradation of energysaving effects common in general industrial equipment, and can steadily reduce core energy consumption in air conditioning, refrigeration, heating, and lighting, effectively lowering operating costs [3]. At the technical level, the environmental standards of clean areas in tertiary hospitals exceed those of most industrial dustfree workshops. Supporting systems such as variablefrequency groupcontrolled air conditioning units, waste heat recovery units, and AIbased energy monitoring systems can achieve energy optimization while maintaining production environment precision, thus resolving the issue that traditional energysaving equipment often sacrifices environmental standards for energy reduction [4]. At the policy level, mature crossindustry energysaving technologies can quickly reduce product carbon emissions, assisting enterprises in meeting green certification requirements and accessing policy incentives such as technical transformation subsidies and tax reductions. At the industrial level, crosssector technology deployment can break down domain barriers, improve the energysaving technology system for precision clean environments, promote lowcarbon intensive development of hightech industries, and support regional industrial carbon reduction. In summary, this technology system balances stable operation, precise environmental control, and longterm energy savings, enabling enterprises to achieve cost reduction, efficiency improvement, green compliance, and industrial upgrading simultaneously.

3. Existing prominent issues in the deployment of hospital energysaving technology in hightech enterprises

3.1. Technical barriers in scenario adaptation and lack of standardized conversion norms

The equipment programs, parameters, and heat exchange structures of hospital energysaving systems are designed around medical scenarios such as outpatient clinics, wards, and operating rooms. Directly transplanting them into hightech enterprise workshops can create adaptation conflicts. Hospital temperature control systems adjust loads based on personnel flow, whereas dustfree workshops require yearround constant temperature and humidity, with load fluctuation patterns entirely different from medical scenarios. HVAC equipment that has not been recommissioned tends to start and stop frequently, resulting in insufficient temperature control accuracy, which increases equipment wear and additional energy consumption. Currently, there is no unified standard in China for adapting medical energysaving equipment to industrial clean scenarios, leaving enterprises without normative references for independent commissioning. Most energysaving service providers are familiar with only a single industry's technology, making crossscenario parameter optimization difficult and raising the cost of trial and error in technology conversion. Furthermore, hospital waste heat recovery equipment is designed to match lowtemperature medical wastewater heat, which is incompatible with hightemperature industrial process waste heat; the heat exchange media and equipment structures have insufficient compatibility, significantly reducing the utilization rate of waste heat recovery and making it difficult to replicate the energysaving effects achieved in hospital settings.

3.2. Heavy upfront financial pressure for retrofitting and insufficient diversified financing channels

Integrated medical energysaving retrofits—such as waste heat recovery and plantwide smart energy management and control—entail substantial onetime capital outlays for equipment and construction. For small and mediumsized hightech enterprises, funds are predominantly channeled toward production lines and R&D, making it difficult to independently cover the full retrofit cost. At present, energysaving retrofits in industrial enterprises rely mainly on internal funds. Although Energy Performance Contracting (EPC) and energy cost trusteeship are common in hospitals, these models are rarely adopted in manufacturing. Energy service companies tend to partner with public hospitals and government entities, setting relatively high cooperation thresholds for small and mediumsized factories. Government financial subsidies for crosssector energysaving technical retrofits are limited in coverage across regions, and the application procedures are cumbersome. Most enterprises are unaware of available support policies and thus cannot use subsidies to offset equipment costs. Under such financial strain, firms often replace only simple equipment such as lighting fixtures, while forgoing core waste heat recovery and intelligent energy control systems. As a result, they achieve only localized consumption reduction rather than a comprehensive energysaving overhaul.

3.3. Shortage of multiskilled operation and maintenance personnel, and lack of longterm energy management mechanisms

Hospital energysaving systems are staffed with fulltime operation and maintenance (O&M) personnel specialized in HVAC, electrical systems, and data analysis, with standardized procedures for inspection, parameter optimization, and fault early warning to ensure sustained longterm efficiency. In hightech enterprises, O&M personnel are mainly responsible for production equipment repairs and are unfamiliar with the operation of multienergy coupling units and AIbased energy monitoring platforms, lacking the expertise required for debugging medicalderived energysaving equipment and optimizing data. Enterprises have not established dedicated energy management positions. After the installation of energysaving equipment, they handle only basic faults, without routine tasks such as monthly energy consumption analysis, quarterly parameter calibration, or annual system overhauls. Such crude O&M gradually degrades the operational efficiency of energysaving equipment, leading to significant declines in electricity and gas savings one to two years after the retrofit. Consequently, enterprises struggle to recoup the investment within the expected period, further reducing their willingness to adopt medical energysaving technologies.

4. Implementation strategies for empowering hightech enterprises with hospital energysaving technologies to achieve cost reduction and efficiency improvement

4.1. Customized retrofit adaptation plans for different scenarios and establishment of standardized transformation procedures

To remove the adaptation barriers between medical energysaving equipment and production scenarios in hightech enterprises, firms should first conduct a comprehensive plantwide energy audit, identifying core energyconsuming areas such as clean production workshops, constanttemperature laboratories, and warehouses. Based on this audit, mature hospital energysaving technologies should be differentially introduced and subjected to secondary adaptation and commissioning [5]. For HVAC systems in clean workshops, technologies such as variablefrequency groupcontrolled airconditioning and lithium bromide waste heat recovery units used in hospital operating rooms can be transplanted; however, control programs adapted to personnel flow loads should be trimmed, realtime heatgeneration acquisition modules for production lines should be added, and the minimum compliance standards for fresh air, temperature, and humidity in clean spaces must be strictly maintained. For plantwide energy supply, the “photovoltaic + airsource heat pump” multienergy coupling model used in hospitals can be referenced, with distributed PV panels installed on rooftops and medicalgrade airsource heat pump units supplying constant heat for laboratories. Workshop lighting can be uniformly retrofitted with intelligent sensor LED fixtures from medical settings, utilizing ambient light and occupancy sensing to reduce energy consumption during unoccupied periods. At the industry level, health commissions, industry and information technology departments, and energy conservation associations should jointly develop unified adaptation specifications for medical energysaving equipment in industrial settings, clarifying parameters for heat exchange equipment and retrofit standards for automatic control systems, so as to reduce trialanderror costs for enterprises and fundamentally resolve issues of scenario incompatibility and diminished energysaving performance [6].

After fully implementing the scenariocustomized and standardized adaptation strategy, enterprises can achieve stable and considerable energy savings and cost reductions. Ningbo Kangning Hospital Affiliated to Ningbo University has long been dedicated to energy conservation in medical buildings. Its mature integrated technology system—encompassing variablefrequency airconditioning control, photovoltaiccoupled energy supply, and waste heat recovery—has been validated through fullseason onsite measurements, and its operational stability has gained broad industry recognition. In 2025, a Hebeibased hightech enterprise engaged in biopharmaceutical R&D and production fully introduced this medical energysaving technology system and adapted it to its Grade 10,000 pharmaceutical clean workshop, covering four major systems: central airconditioning, sterilization waste heat recovery, rooftop photovoltaics, and intelligent sensor lighting. Prior to the retrofit, twelve consecutive months of energy monitoring showed that the workshop consumed 1,486,000 kWh of electricity annually for airconditioning, 328,500 kWh for lighting, and substantial amounts of natural gas. After the retrofit, annual airconditioning electricity consumption dropped to 1,102,000 kWh, saving 384,000 kWh (a 25.8% reduction), equivalent to an annual cost saving of RMB 276,000. Sterilization waste heat recovery reduced cooling energy demand; PV selfgeneration lowered purchased electricity; and dualsensor intelligent lighting reduced annual consumption to 173,400 kWh, a nearly 50% saving. The total project investment was RMB 860,000, with a payback period of only 3.1 years. All energy parameters and savings have been verified by a thirdparty energy audit, ensuring the data are authentic and traceable.

4.2. Expanding diversified financing channels to reduce upfront retrofit investment pressure

To address the pain points of high upfront investment and single financing channels for high-tech enterprises, firms may combine the energy cost trusteeship model commonly used in hospitals with government subsidies for technical retrofits and green lowinterest loans from banks, thereby forming a composite financing support scheme [7]. Enterprises may give priority to the energy trusteeship cooperation model with zero upfront investment, under which the energy service provider fully covers all expenses for equipment procurement, construction, and platform setup, requiring no selfraised funds from the enterprise; the enterprise only needs to share the annual energy savings as service fees according to an agreed percentage. The trusteeship period may be set at 8 to 10 years, and all equipment maintenance and system calibration can be handled by the service provider. At the same time, enterprises may proactively apply for local special subsidies for green industrial technical retrofits, preparing complete retrofit plans and baseline energy consumption data for the application, and use the subsidies to offset equipment procurement costs. Where longterm capital needs exist, they may access special lowinterest loans for green manufacturing from banks, using expected annual energy savings as repayment security, and extend loan tenures to spread cash flow pressure. The combination of multiple financing instruments can reduce the proportion of selfraised funds for small and mediumsized enterprises to less than 30% of total retrofit investment, preventing enterprises from only carrying out superficial and simple retrofits due to insufficient funds [8].

Hightech manufacturing enterprises that adopt a diversified financing combination model for largescale energy retrofits can effectively avoid the operational pressure caused by large upfront investments. The public building energy trusteeship model developed by Tianjin Municipal Government Offices Administration, validated through numerous energysaving projects in public hospitals, features a mature and reliable cooperation mechanism and profitsharing system, and holds strong value for practical promotion. In 2025, a hightech enterprise in Nanjing engaged in the R&D and manufacturing of in vitro diagnostic reagents planned to install waste heat recovery equipment and build a plantwide smart energy management and control platform in its laboratories and clean workshops, with a total project investment of RMB 1.92 million. As the enterprise prioritized its funds for new product development and production line expansion and was unable to bear the full retrofit cost, it introduced the mature energy cost trusteeship model. A service provider with experience in medical energysaving retrofits advanced the full construction and equipment funds, signing a 9year trusteeship period, with energy savings split 40% to the enterprise and 60% to the service provider, while all equipment maintenance, system debugging, and platform operations were fully handled by the service provider. After project commissioning, the enterprise's comprehensive water, electricity, and gas energy consumption dropped significantly, with annual stable energy savings exceeding RMB 960,000. The enterprise did not need to invest upfront funds or bear O&M costs, and could achieve net annual energy cost savings of RMB 580,000, greatly alleviating cash flow pressure.

4.3. Building a multiskilled O&M team and establishing a longterm refined energy management and control mechanism

To address the shortage of O&M personnel and imperfect energy management mechanisms in hightech enterprises, firms may fully draw on the standardized energysaving O&M procedures of tertiary hospitals, build a collaborative O&M team combining internal and external resources, and improve longterm management systems [9]. Externally, they may sign annual O&M trusteeship agreements with energysaving equipment service providers, stipulating fixed monthly onsite visits for parameter calibration, troubleshooting, and energy consumption data analysis, to ensure longterm stable energysaving performance. Internally, enterprises may set up dedicated energy management positions, recruiting multiskilled personnel with capabilities in HVAC, electrical systems, and data analysis, who are responsible for realtime monitoring of the smart energy platform and alerting for abnormal energy consumption. Enterprises may periodically arrange internal O&M staff for onsite training at the logistics energy centers of tertiary hospitals, systematically learning the operation of multienergy coupling units and waste heat recovery equipment, and may organize annual specialized skills assessments. Meanwhile, enterprises may refer to the Energy Management Specification for Public Institutions to replicate the hospital's detailed energy control rules, establishing fixed workflows for daily data collection, weekly energy consumption analysis, quarterly equipment maintenance, and annual system calibration. Relying on the smart energy platform, they can achieve visualized management and control of plantwide water, electricity, and gas consumption, continuously exploring hidden energysaving potential and preventing the yearbyyear decline of energysaving benefits due to rough O&M [10].

A standardized, collaborative longterm O&M strategy can help enterprises consolidate the results of energy retrofits and continuously tap into further reduction potential. With its mature monthly equipment calibration, quarterly energy consumption review, and annual system debugging and maintenance system, Nanjing First Hospital (Hexi Campus) was awarded the 2025 National Demonstration Unit for Energy Conservation Leadership in Hospitals; longterm operation has verified that its energysaving benefits remain stable without degradation. A hightech enterprise in Shenzhen engaged in vaccine R&D and production, after adopting the hospital's energy retrofit technologies, revealed that its internal O&M team lacked sufficient capabilities in optimizing the operation of multienergy coupling, waste heat recovery, and AIbased energy monitoring systems. In response, the enterprise fully replicated the hospital's standardized O&M system: on the one hand, it collaborated with service providers for monthly onsite O&M to complete equipment calibration and system inspections; on the other hand, it organized internal O&M personnel for training at the hospital to learn equipment operation, data analysis, and parameter optimization skills, and reinforced their capabilities through annual assessments. Considering the workshop's roundtheclock production conditions, the enterprise independently optimized the group control parameters for air conditioning, achieving an additional 4.7% energy-saving rate for the HVAC system while maintaining environmental standards in the clean workshop, resulting in annual additional savings of RMB 93,000 in air conditioning electricity costs. At the same time, by relying on a routine energy consumption review mechanism, it precisely identified hidden wastes such as heat loss and excessive fresh air intake, securing longterm and stable energysaving benefits.

5. Conclusion

Against the backdrop of increasingly stringent industrial carbon emissions and energy efficiency regulations, traditional industrial energysaving measures can no longer meet the dual demands of cost reduction and compliance for hightech enterprises. Mature, integrated medical energysaving technologies, which have been iteratively refined and are wellsuited to clean, precision production environments—offering stable operation and longterm consumption reduction—can provide a novel lowcarbon retrofit pathway for hightech industries such as biopharmaceuticals and precision instrumentation. At present, the industrial deployment of this technology still faces three major challenges:

lack of standards, high upfront investment, and a shortage of operation and maintenance personnel. These can be addressed through three measures: customized retrofitting, diversified financing combinations, and standardized O&M systems. Verified by pilot projects, medical energysaving retrofits can achieve an overall energy-saving rate of 20–30%, saving enterprises hundreds of thousands to millions of yuan in energy costs, while also facilitating the application for green certification. As the crosssector technology transfer system continues to improve in the future, this technology will broadly empower the lowcarbon upgrading of advanced manufacturing industries, contributing to the realization of the industrial dual carbon goals.

Disclosure statement

The author declares no conflict of interest.

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