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The Effect of Artificial Intelligence Technology on Carbon Emissions

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Master in Digital Technologies for Business

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March, 2025

TECNOLOGIAS
E ARQUITETURA

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Abstract

As the new wave of technological revolution and industrial transformation advances, artificial intelligence technology plays a crucial role in addressing climate change and empowering the achievement of “peak carbon emissions” and “carbon neutrality” goals.

This study conducts a systematic review of four key variables: AI orientation, green technology innovation, environmental regulation, and carbon emissions. Drawing upon strategic management theory, technological innovation theory, and low-carbon economic theory, it proposes research hypotheses and constructs corresponding theoretical models. Descriptive statistics and correlation analysis are employed to validate the relationships among these variables, yielding significant empirical findings. Firstly, both enterprise artificial intelligence orientation and green technology innovation exert substantial suppressive effects on carbon emissions. Secondly, AI orientation effectively stimulates the enhancement of green technology innovation. Thirdly, AI orientation impacts carbon emissions through its influence on green technology innovation. Furthermore, environmental regulation is identified as a positive moderator of the relationship between green technology innovation and carbon emissions.

In conclusion, based on the empirical analysis, this study identifies theoretical contributions and managerial insights while outlining research limitations and future directions. In light of the “dual carbon” objectives, prioritizing green and low-carbon development is crucial. Developing AI technologies aligned with these goals and guiding their application in carbon emission reduction are essential strategies. Additionally, tailoring development policies to the unique contexts of different regions is imperative for effective implementation.

Keywords:

Artificial intelligence technology, carbon emissions, energy utilization efficiency

Resumo

À medida que a nova onda de revolução tecnológica e transformação industrial avança, a tecnologia de inteligência artificial desempenha um papel crucial no enfrentamento das mudanças climáticas e empoderamento da consecução dos objetivos de "pico de emissões de carbono" e "neutralidade de carbono".

Este estudo realiza uma revisão sistemática de quatro variáveis-chave: orientação para IA, inovação em tecnologia verde, regulação ambiental e emissões de carbono. Baseando-se na teoria da gestão estratégica, teoria da inovação tecnológica e teoria econômica de baixo carbono, propõe hipóteses de pesquisa e constrói modelos teóricos correspondentes. A estatística descritiva e a análise de correlação são empregadas para validar as relações entre essas variáveis, produzindo achados empíricos significativos. Em primeiro lugar, tanto a orientação de inteligência artificial empresarial quanto a inovação em tecnologia verde exercem efeitos supressores substanciais sobre as emissões de carbono. Em segundo lugar, a orientação da IA estimula efetivamente o aprimoramento da inovação tecnológica verde. Em terceiro lugar, a orientação da IA impacta as emissões de carbono através de sua influência na inovação tecnológica verde. Além disso, a regulação ambiental é identificada como um moderador positivo da relação entre inovação tecnológica verde e emissões de carbono.

Em conclusão, com base na análise empírica, este estudo identifica contribuições teóricas e insights gerenciais, delineando limitações de pesquisa e direções futuras. À luz dos objetivos de "duplo carbono", priorizar o desenvolvimento verde e baixo carbono é crucial. Desenvolver tecnologias de IA alinhadas a esses objetivos e orientar sua aplicação na redução de emissões de carbono são estratégias essenciais. Além disso, adaptar as políticas de desenvolvimento aos contextos únicos das diferentes regiões é imperativo para uma implementação eficaz.

Palavras-chave:

Tecnologia de inteligência artificial, emissões de carbono, eficiência de utilização de energia

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Chapter 1 Introduction

In modern society, artificial intelligence (AI) technology is rapidly emerging as a key driving force for the transformation of various industries [1-2]. From automated manufacturing to advanced data analysis, AI has a broad range of applications, significantly reshaping business operations and redefining the boundaries of innovation on a global scale. Particularly in the context of global climate change, AI's potential in reducing carbon emissions and promoting sustainable development has garnered widespread attention from the scientific community, industry, and policymakers. However, while AI offers numerous environmental benefits, its implementation and operation also entail significant energy consumption, especially in maintaining data centers and network infrastructure, which may, in turn, contribute to increasing carbon emissions [3-4].

Carbon emissions are among the primary drivers of global climate change, predominantly stemming from the combustion of fossil fuels such as coal, oil, and natural gas. These emissions exacerbate the greenhouse effect, leading to rising global temperatures, more frequent extreme weather events, and severe disruptions to ecosystems and biodiversity. In this evolving landscape, AI has been increasingly leveraged to mitigate environmental impacts by optimizing resource use and improving energy efficiency [5-6]. Through advanced algorithms and computing power, AI can process and analyze massive datasets, facilitating data-driven decision-making, enhancing operational efficiency, and optimizing energy distribution. Given the urgent need to address climate change, the role of AI in achieving carbon neutrality and sustainable development goals has become a critical research focus. AI-driven technologies are being integrated into energy systems, transportation networks, industrial manufacturing, and waste management to reduce carbon footprints. For instance, AI can optimize power grid operations to integrate renewable energy sources more effectively, reduce traffic congestion through intelligent transportation systems, and enhance energy efficiency in production processes. Nevertheless, despite these promising applications, the substantial energy demand of AI technologies—particularly the computational power required for training and maintaining machine learning models—raises concerns about their net environmental impact.

Previous studies have mainly focused on the positive impacts of AI in isolated domains such as intelligent manufacturing, energy management, and traffic optimization, emphasizing its potential to enhance energy efficiency and reduce carbon emissions. However, these investigations often address only specific application areas or localized effects without considering the comprehensive influence of AI across entire industrial processes. In particular, there is a lack of systematic analysis on the dual impact of AI—balancing its environmental benefits against the high energy consumption required for data processing and model training.

Moreover, existing research tends to overlook the roles of environmental regulation, cross-industry collaboration, and public awareness in facilitating effective AI deployment for carbon reduction. These aspects are critical, as they can significantly moderate the overall effectiveness and sustainability of AI applications.

To address these gaps, this study proposes an integrated theoretical model that examines the interrelationships among corporate AI orientation, green technological innovation, and environmental regulation. By doing so, it aims to comprehensively evaluate the net effects of AI on carbon emissions while considering both its beneficial and adverse impacts. This research objective not only bridges the current knowledge gap but also provides a robust theoretical foundation to justify the promotion of AI-driven strategies in achieving carbon neutrality.

The paradox of AI's environmental role stems from the fact that, while it enables numerous carbon reduction strategies, its own operations require substantial amounts of electricity. Training state-of-the-art AI models can consume energy equivalent to the annual electricity usage of hundreds of households. Moreover, the majority of data centers still rely on fossil fuel-based power sources, thereby amplifying AI's carbon footprint. Although AI has the potential to drive efficiency improvements across multiple sectors, the deployment of low-carbon AI solutions remains limited due to technological and infrastructural disparities. This is especially evident in developing regions, where resource constraints hinder the large-scale adoption of AI-driven sustainability measures. Furthermore, while AI's ability to optimize energy use and reduce emissions is well-documented, its widespread implementation faces technological, regulatory, and economic challenges that need to be addressed to realize its full potential.

At the policy level, existing regulatory frameworks for AI and environmental sustainability are still underdeveloped. A lack of standardized evaluation metrics for assessing AI's environmental impact poses a significant challenge to formulating effective policies. Without unified guidelines, global efforts to promote sustainable AI practices remain fragmented, limiting their effectiveness in tackling climate change. Additionally, the concept of "technological determinism"—the assumption that AI-driven solutions alone can resolve environmental issues—may overshadow the necessity of fundamental structural changes in production and consumption patterns. Over-reliance on AI could lead to complacency, diverting attention from the urgent need for systemic policy reforms and shifts in social behavior that are critical for achieving long-term sustainability.

Given these complexities, this study aims to comprehensively explore the relationship between AI technologies and carbon emissions, evaluating both the opportunities and challenges AI presents in reducing environmental impact.

Specifically, the research would examine how AI enhances energy efficiency, optimizes resource allocation, and contributes to carbon mitigation across various industries. By identifying existing

research gaps, the study provides insights into the environmental implications of AI deployment and propose strategic recommendations for aligning AI development with global sustainability goals.

In doing so, it would underscore the importance of balancing AI’s environmental benefits with its energy-intensive nature, emphasizing the need for continued technological advancements, regulatory frameworks, and responsible AI deployment. Future efforts should focus on developing energy-efficient AI algorithms, integrating AI with low-carbon energy sources, and establishing global standards for evaluating AI's environmental footprint. In summary, while AI has the potential to serve as a transformative force in combating climate change, ensuring that it operates in an environmentally responsible manner remains a crucial challenge that must be addressed through interdisciplinary collaboration and sustainable innovation.

Chapter 2 Literature Review

Rigorous inclusion and exclusion criteria are used to enhance the rigor of the review process. The inclusion criteria require that the included literature be peer-reviewed journal articles, conference papers, or reports from reputable institutions that focus on the relationship between AI technologies, carbon emissions, green technology innovation, and environmental regulation. Only studies published within the last ten years are considered to ensure the relevance and timeliness of the findings. In addition, both quantitative and qualitative studies are included, provided they provide empirical evidence or theoretical insights to support.

Understanding the background and related risks of AI is crucial when exploring its impact on carbon emissions. The application of AI technology in multiple fields such as environmental science, industrial automation, and traffic management has demonstrated its potential to reduce carbon footprint. By optimizing energy use through intelligent systems, maximizing resource efficiency, and predicting and managing energy demand through advanced algorithms, AI helps to reduce ineffective and excessive energy consumption. In addition, the application of AI in the field of renewable energy, such as optimizing the efficiency of wind and solar power generation, has also demonstrated its important contribution to sustainable environmental development. However, the implementation of AI technology also comes with significant environmental risks. One of the biggest risks is its own energy demand. AI models, especially deep learning models, require a large amount of data processing and computing resources, which often rely on large-scale data centers, which consume huge energy and often rely on non-renewable energy. In addition, the widespread application of AI technology may lead to new power supply demands and increased carbon emissions [7]. The risk also includes potential inequalities that may arise during the implementation of technology. Technology is highly concentrated in developed countries, which may exacerbate technological backwardness and environmental pressure in the southern regions of the world [8]. The lack of international cooperation and global strategies may slow down the global promotion of low-carbon technologies, limiting the full realization of AI's carbon reduction potential. In short, the impact of AI technology on carbon emissions is a double-edged sword, with both enormous environmental potential and significant risks and challenges that cannot be ignored. Understanding these backgrounds and risks is the foundation for conducting deeper research and developing effective strategies aimed at maximizing the environmental benefits of AI while minimizing its potential negative impacts [9].

2.1 Overview of AI's Role in Addressing Climate Change

In recent years, with the intensification of global climate change issues, governments and international organizations have increasingly focused on reducing carbon emissions. In this context, AI technology is seen as an important tool that has the potential to help mitigate the impact of climate change by optimizing energy use, improving resource efficiency, and directly reducing emissions from industrial activities. However, the implementation and operation of AI technology also come with significant energy consumption, which may in itself increase carbon emissions. Therefore, this study is committed to exploring the complex relationship between the environmental benefits and costs of AI.

In order to gain a deeper understanding of the impact of AI technology on carbon emissions, many scholars have conducted specific theoretical discussions and empirical research. These studies elucidate from different perspectives how AI can reduce global carbon footprint by improving efficiency, optimizing resources, and directly reducing emissions, while also revealing the environmental costs and challenges brought about by AI technology itself.

Pioneering Studies on AI's Environmental Impact

Gao & Peng's [10] research: This study marked a significant exploration into the environmental impacts of training complex ML models, such as NLP Transformers. It detailed the substantial energy consumption and carbon emissions associated with AI training, equivalent to the carbon output of an average Western household over two months. The findings underscored the necessity for more efficient computing methods and hardware optimization.

Glover's [11] study on ML: Investigated ML applications across different aspects of climate change, including meteorological forecasting and precision agriculture. The study illustrated how AI's precision in data analysis can enhance sustainable environmental management and operational efficiency across sectors.

Sector-specific AI Applications and Their Environmental Implications

Energy Efficiency in Buildings (Guo et al.) [12]: Discussed how AI can improve energy management in the industrial and construction sectors through intelligent monitoring and automated systems, significantly reducing energy consumption and emissions. It highlighted how AI can enhance energy efficiency in the industrial and construction sectors. Implementing intelligent monitoring systems and automated management can dramatically lower building energy consumption and reduce greenhouse gas emissions. The researchers also addressed challenges such as the costs of technology, user acceptance, and the need for supportive regulations and policies.

Renewable Energy Optimization (Henderson et al.) [13]: Highlighted AI's capability to enhance renewable energy usage by optimizing energy demand and supply in smart grids. It showcased how AI can optimize renewable energy use by predicting and balancing energy demand and supply in smart

grids. Their models can accurately forecast wind and solar power production, optimizing resource scheduling and minimizing reliance on fossil fuels.

Urban Transportation (Hirth and Krittanawong et al.) [14-15]: Detailed how AI can reduce congestion and improve fuel efficiency through intelligent traffic management systems and dynamic route planning. They focused on intelligent traffic lights and dynamic route planning, which can adjust traffic flow in real-time, reducing waiting times and unnecessary driving, thereby cutting down car exhaust emissions. Their researches proved that AI-driven route planning and traffic flow optimization significantly lessen travel times and fuel consumption, thus reducing urban carbon emissions.

2.2 Challenges in AI Deployment for Environmental Sustainability

The implementation of AI technologies faces several hurdles, from the high energy demands of AI systems, particularly in data centers, to the significant initial capital required for deployment. Furthermore, social acceptance issues, the need for supportive regulations, interdisciplinary collaboration, and clear policy directives pose additional challenges. These include:

Social Acceptance (Lee & Mackey, and Leo) [16-17]: Discussed public trust and privacy concerns that hinder AI's widespread adoption. They discussed the social acceptance issues of the widespread application of AI technology, pointing out that although AI has enormous potential in environmental protection, public trust in AI and concerns about privacy and data security remain the main obstacles to its widespread application. Their researches emphasized the need to establish stricter privacy protection and data security regulations before popularizing AI applications.

Economic Costs (Leone et al. and Ligeza) [18-19]: Considered the high initial costs and discusses potential economic strategies such as government subsidies to facilitate AI adoption. They focused on the economic costs of AI technology, especially the high investment costs in the initial deployment phase. They also discussed how to lower the threshold for companies to adopt AI technology through government subsidies and tax incentives and promote the application of AI technology in environmental protection projects.

Expanded AI Applications Across Sectors

Energy Sector and Smart Grids (Lin et al.) [20]: This study emphasized AI’s role in enhancing renewable energy management through smart grids. By predicting and balancing energy supply and demand, AI reduces dependence on fossil fuels and offers strategies for integrating and optimizing dispersed energy resources. This conclusion supported the narrative on how AI aids in making energy systems more sustainable and efficient.

Supply Chain Management (Schumpeter and Shi et al.) [21-22]: AI's impact on supply chain management is crucial in reducing carbon emissions during transit. By optimizing transportation routes

and loads, AI significantly enhances the environmental sustainability of supply chains, aligning with broader efforts to decrease logistical carbon footprints.

Agriculture (Steffen et al.) [23]: In agriculture, AI's role in precision farming techniques—like monitoring water and fertilizer use—helps reduce the environmental burden of overfertilization and excessive water usage, which are critical factors in sustainable agriculture practices. This usage of AI not only boosts crop yield but also minimizes negative environmental impacts.

Challenges and Strategic Considerations

Energy Efficiency Issues (Strubell et al.) [24]: This research directly addressed the high energy consumption of AI systems, particularly in data centers. It highlighted the need for developing low-energy AI computing methods and improving overall energy efficiency in critical infrastructure, which is essential for making AI's environmental footprint more sustainable.

Interdisciplinary Collaboration (Teece and Van & Misuraca) [25-26]: They found that the challenges of implementing AI in environmental projects often stem from the need for effective interdisciplinary collaboration. The recommendation to establish an international cooperation framework for knowledge and technology sharing reflects the global scale of environmental challenges and the need for a unified approach in AI applications.

Policy Support (Wainstein & Bumpus and Wang et al.) [27-28]: The role of policy-making is emphasized as a critical factor in promoting AI to reduce carbon emissions. Developing forward-looking policies that incentivize the adoption of AI in environmental protection can address the gap between technological capabilities and their real-world applications due to regulatory and policy barriers.

In Summary, in the review of research on the impact of AI technology on carbon emissions, we can see the enormous potential and challenges faced by AI technology in environmental protection and sustainable development. AI technology demonstrates various possibilities for reducing carbon emissions by optimizing resource utilization, improving energy efficiency, and promoting the integration of renewable energy. Scholars' research has not only revealed the application prospects of AI in various fields, but also emphasized its practical benefits in environmental protection. However, these positive potentials are accompanied by significant challenges, including technological efficiency, energy demand, economic costs, policy support, and social acceptance. These challenges need to be overcome through policy formulation, technological innovation, interdisciplinary cooperation, and international collaboration. Future research needs to continue exploring how to optimize the energy efficiency of AI technology, reduce its own environmental footprint, while also developing new policies and economic strategies to reduce the implementation costs of AI technology and promote its widespread acceptance on a global scale. In summary, the impact of AI technology on carbon emissions is a multi-faceted and multidimensional issue, involving various aspects of technology, economy, policy,

and society. Through continuous research and innovation, as well as global cooperation and policy support, AI technology is expected to become an important driving force for sustainable environmental development in the future. This requires practitioners, scholars, and policy makers to work together to ensure that the development direction and application of AI technology can effectively support global environmental and climate goals.

2.3 Strategic Management Theory

“Strategy” was originally applied in the military field, referring to the plans and tactics formulated by military commanders for commanding troops in battle, this concept has been further applied by researchers Chen et al. in other aspects [29]. Since the application of "strategy" in enterprise management, it has transformed into plans and strategies for enterprises to adapt to the future environment and seek long-term survival and development, providing crucial guidance for the survival and development of enterprises. The core of strategic management theory mainly revolves around three questions: Where is the company? Where is the company going? When should the company take action? This is also consistent with Mintzberg’s “5 Ps” view of strategy, which states that strategy is a plan, a ploy, a pattern, a position, and a perspective. Therefore, the importance of strategic management for the development of enterprises is self-evident [30].

Since the establishment of the discipline of strategic management, numerous academic schools of thought have gradually emerged, and scholars have provided different interpretations of strategic management from various perspectives, promoting the continuous and vigorous development of the discipline. Michael Porter is a renowned strategic management scholar who believes that effective strategic management requires a value orientation, value chain, trade-offs, interactivity, and sustainability [31]. Regardless of the academic school of thought, these points are indispensable. Among them, the viewpoints of the natural selection school and the resource allocation strategic school provide a certain theoretical basis for this study. The natural selection school emphasizes that the formulation of a company's strategy should be based on the external environment to plan organizational behavior, thereby rationalizing market competition. In the view of the resource allocation strategic school, resource allocation is crucial and can promote the interaction between internal resources and the environment, thus forming a reasonable trend for business development [32].

The development process of strategic management theory mainly includes four periods: 1) the period of attention to the external environment: around 1960, the design school and the planning school had similarities in their discussions on strategic issues, viewing a company's strategy as an adaptation to the external environment. 2) The competition-oriented period: around 1980, schools of

thought represented by Porter believed that maintaining core competitiveness is the focus of corporate strategy formulation. 3) The period of attention to the internal environment: by 1990, with an increase in market entities and intensified competition, many companies had to shift their development focus to the internal organization and began to effectively restructure unique resources to establish the core capabilities of enterprises. 4) The win-win cooperation period: entering the 21st century, intensified market competition through survival of the fittest mechanisms has forced companies to shift from overemphasizing competition and neglecting cooperation in the past to focusing more on resource development and accumulation, as well as emphasizing cooperation between departments, between enterprises, and between industries [33].

2.4 Technological Innovation Theory

Economist Schumpeter creatively proposed the “technological innovation theory” in his work "The Theory of Economic Development." In his view, the essence of innovation is to create new production functions by optimizing the production system through the integration of production conditions and elements, focusing on innovation in products, production methods, markets, suppliers, and organizational forms. However, innovation is not simply an isolated project but an ongoing mechanism. Only when it is applied in actual production and impacts the original production system can it be considered as innovation [34]. Technological innovation is one way to achieve this.

Throughout history, the academic community has not yet reached a unified definition of “technological innovation.” Schumpeter believed that it is essential to realize technological innovation through identifying a specific innovation field, ensuring sufficient investment, establishing a scale organization, formulating operational plans, recruiting labor, and opening up new markets. Schumpeter believed that demand-driven innovation is the fundamental driving force behind technological creation. Market, as an intermediary condition, affects the speed of technological innovation, and changes in the structure of social demand also influence the direction of technological innovation [35]. Therefore, enterprises must have foresight and insight, accurately grasp market demand, promote technological innovation, and reap benefits. Entrepreneurs in China believe that technological innovation is led by entrepreneurs, using innovative knowledge and new technologies to develop new products, adopt new production and operation models, seize potential profit opportunities for enterprises, and gain competitive advantages, aiming to maximize benefits [36].

Through the analysis of technological innovation theory, it is found that the main subject of innovation can only be the enterprise. Enterprises have a demand for technological innovation, and to seek long-term survival and development, innovative capabilities are indispensable. Research institutions and universities are the main sources of technological innovation, yet they do not actively

carry out technological innovation based on market demand and trends. Therefore, only enterprises can be considered the main body of technological innovation. Enterprises that have a demand for technological innovation and have the ability to apply new technologies to actual production and transform innovation into benefits can be the carriers of innovation.

2.5 Low-Carbon Economy Theory

Since the Industrial Revolution, human activities have led to continuous degradation of the environment and atmospheric conditions. Based on this situation, in 2003, the UK released "Our Energy Future: Creating a Low Carbon Economy," proposing the concept of a "low-carbon economy." Although "low-carbon economy" is a new concept, its aim is to pursue economic development while paying attention to the consumption of natural resources and the emissions of greenhouse gases. UK scholar Rubinstein pointed out that the low-carbon economy is an unprecedented economic model. It is still regulated by market mechanisms and aims to promote the development and application of energy-saving, renewable energy, and harmful gas reduction technologies based on constructing a new framework and formulating corresponding policies, thereby driving the overall social economy towards greening and low carbonization transformation [37]. Chinese scholars have different views on the meaning of a low-carbon economy. In the view of Bai et al., clean energy and energy efficiency are the key aspects of a low-carbon economy, requiring greater investment in scientific and technological progress and completing institutional reforms at the same time [38]. Chen et al. pointed out that the premise of a low-carbon economy is not to affect normal economic development, achieved through promoting mechanisms and technological innovation to realize the conservation of various resources [39]. In 2009, the China Council for International Cooperation on Environment and Development released a study on the approach to developing a low-carbon economy in China, defining a low-carbon economy as a new development model, primarily characterized by being more energy-efficient, efficient, and low-emission compared to traditional economies, while achieving economic development, thus signifying sustainable and green development.

With the depletion of energy resources and the continuous deterioration of the climate and environment, countries worldwide have gradually realized the importance of energy conservation and emission reduction. The implementation of a low-carbon economy has been put into practice in increasingly more countries and regions. The Italian government has formulated corresponding policies and taken corresponding measures to promote the country's economic development by focusing on energy conservation and emission reduction and intensifying the development of low-carbon technologies. Sweden has deeply integrated the low-carbon concept of energy conservation and emission reduction into every aspect of life. The Swedish government has continuously

encouraged citizens to purchase vehicles running on clean fuels and implemented corresponding incentive measures. After continuous efforts by the Swedish government, Sweden has become a role model for countries around the world.

A low-carbon economy means effectively reducing greenhouse gas emissions while maintaining a balanced development between environmental protection and economic development. The development mode of a low-carbon economy can effectively promote the sustainable development of ecological resources, responding to the national call, implementing the low-carbon concept, and promoting a win-win situation for the economy and the environment. On the other hand, adjusting the industrial structure, changing production and operation methods, conserving energy and reducing emissions, and developing green industries are required. This demands the simultaneous development of the economy and the environment, no longer adopting the development model of pollution first and then governance or low-end development preceding high-end development; it is the necessary path to achieve economic prosperity and a good ecological environment.

Chapter 3 Research Methodology

3.1 Research Design

This study explores the impact of AI technology on carbon emissions through a questionnaire survey, aiming to collect extensive and specific data to analyze the actual effects of AI technology application and potential environmental cost analysis. The choice of questionnaire survey method is based on its multiple advantages: it can quickly and effectively collect data from large-scale target groups, which is particularly important for research covering multiple demographic characteristics and geographical locations; By using standardized question formats, it is possible to ensure that comparable and consistent data is collected from each participant, which is the basis for conducting quantitative analysis and generalizing research results; The flexibility of questionnaire surveys allows researchers to adjust questions based on feedback from predictive experiments, thereby optimizing overall survey design and improving data quality[40-42].

The purpose of this questionnaire is to systematically collect and analyze the perceptions and experiences of various audiences on the application effects, advantages and potential disadvantages of AI technology in carbon emission reduction. By designing questions covering multiple dimensions such as basic demographic information, technical cognition, practical application effect, and support for environmental regulation, the questionnaire can comprehensively capture the views of respondents at different levels, so as to provide empirical support for the relationship between enterprise AI orientation, green technology innovation and environmental regulation in the construction of theoretical models. At the same time, the design of the questionnaire can also help to reveal the differences in technology acceptance, environmental awareness and practical practices of different groups, ensure that the data collected is extensive and representative, and provide a solid data foundation for subsequent policy formulation and technological improvement.

The content design of this survey focuses on evaluating the specific applications of AI, such as intelligent manufacturing, energy management, transportation systems, and how these technologies can help reduce carbon emissions. In addition, by setting questions to explore the respondents' views on environmental regulation, technological innovation, and climate change responsibility, it helps to understand the differences between public perception and industry practice, as well as how these differences affect the acceptance and efficiency of technology.

This survey also considered the validity and reliability of its research, ensuring clear and unambiguous expression of the questions through predictive experiments, and verifying data consistency by setting strong logical tracking questions. In addition, to ensure the breadth and depth

of data collection, the questionnaire adopts a mixed question type, combining multiple-choice and open-ended questions, which can obtain standardized statistical data and collect richer qualitative information.

In summary, through the method of questionnaire survey, this study aims to gain a deeper understanding of the environmental benefits and limitations of AI technology in practical operations, thereby providing an empirical basis for formulating more effective policies and technological solutions.

In this chapter, the structure of the questionnaire is designed into several main parts to ensure comprehensive and systematic collection and research related data. The beginning of the questionnaire includes a brief introduction, explaining the purpose and importance of the survey, as well as the commitment of participants to confidentiality and anonymous processing of information. This aims to build trust among participants and encourage them to provide truthful and detailed answers.

3.2 Questionnaire Structure

The content of this survey questionnaire is divided into several different regions, each targeting different research questions. This includes a series of multiple-choice questions aimed at collecting basic demographic information of participants, such as age, gender, educational background, and occupational field. This helps with group segmentation and data hierarchy analysis in subsequent analysis. Explore the participants' perceptions and attitudes towards the role of AI technology in reducing carbon emissions through rating scale questions. The questionnaire also includes several scenario analysis questions, requiring participants to predict or evaluate possible outcomes and impacts based on given environmental changes or technological application scenarios. These questions aim to evaluate the participants' in-depth understanding and critical thinking abilities regarding the impact of technology. The questionnaire also includes open-ended questions that allow participants to freely express their views and insights on the relationship between AI technology and environmental sustainability. The design of these questions aims to gain deeper insights and opinions, supplementing details that may not have been covered by multiple-choice and scale questions [43-45].

The design of the questionnaire in this study not only considers logical fluency and user experience, ensuring that the order and structure of the questions can naturally guide participants to complete the questionnaire, but also reduces possible comprehension difficulties or questions. Through this comprehensive questionnaire structure, research can capture rich data on the role of AI technology in carbon emission reduction from multiple perspectives, providing a solid foundation for subsequent analysis and discussion.

3.3 Sample Selection and Data Collection

In this study, the selection of samples and data collection methods were carefully designed to ensure the accuracy and reliability of the collected data, thereby effectively evaluating the impact of AI technology on carbon emissions. The sample selection process was guided by the research objectives and specific questions that needed to be addressed. The target population included professionals, scholars, policymakers, and members of the general public engaged in related industries, ensuring that insights and data were gathered from multiple perspectives.

To enhance the representativeness and breadth of the data, this study employed a stratified random sampling method. This approach allowed researchers to maintain control over the number of respondents from various predefined subgroups while ensuring sample diversity. The stratification criteria included industry type, geographic region, and work experience, ensuring that each stratum contained a sufficient sample size for reliable statistical analysis. Participants were required to meet certain inclusion criteria: (1) individuals must have a basic understanding of AI technology and/or environmental sustainability policies, (2) they should be actively working in or researching fields related to AI, environmental science, or policy development, and (3) they needed to have at least one year of experience in their respective professional domains. These criteria ensured that the collected data reflected informed perspectives relevant to the study's objectives.

Regarding the data collection process, an online questionnaire survey was chosen due to its cost-effectiveness, efficiency, and broad accessibility. The survey was conducted using Wenjuanxing, a widely used online survey platform, ensuring streamlined data collection and real-time response tracking. The questionnaire was distributed to participants between May and June 2024, leveraging multiple channels, including email, professional networking platforms, and social media (such as LinkedIn and WeChat public accounts). By using these distribution channels, the study aimed to maximize outreach and encourage participation from a diverse set of respondents.

To increase response rates and participant engagement, the survey introduction explicitly outlined the anonymity of responses, the study's purpose, and its potential societal contributions, emphasizing that participants' insights could directly inform the development of relevant policies and technological advancements. Additionally, to ensure data quality and accuracy, multiple validation checkpoints were incorporated throughout the survey process. These included mandatory responses, logical consistency checks, and attention filter questions to minimize errors and identify inconsistent or incomplete responses. After data collection, professional data analysis software was used for data cleaning and preprocessing, eliminating invalid or outlier responses to maintain the integrity and usability of the dataset.

Ultimately, these processed data can undergo statistical analysis to validate the research hypotheses and provide in-depth insights into the effectiveness of AI technology in reducing carbon emissions. Through a carefully designed sample selection process and a structured data collection strategy, this study ensures the collection of high-quality data, forming a solid empirical foundation for evaluating AI's role in achieving sustainability goals.

After data collection, the study employed regression analysis to examine the relationship between AI technology adoption and carbon emission reduction. First, the collected data were cleaned to remove incomplete or inconsistent responses, ensuring the reliability of the dataset. Then, descriptive statistics were used to summarize the characteristics of the respondents, such as their industry background, geographic distribution, and experience level. To quantitatively assess AI's impact on carbon emissions, the study applied a regression model, with AI adoption as the independent variable and carbon emission reduction as the dependent variable. Control variables, such as industry type and regional economic development level, were included to account for external influencing factors. The regression results provided insights into the strength and significance of AI's role in carbon reduction, helping to determine whether increased AI adoption correlates with improved environmental outcomes. Finally, the findings were interpreted in the context of existing literature, highlighting practical implications for policymakers and industry stakeholders. This structured analysis ensured that the study's conclusions were data-driven and robust.

3.4 Ethical Considerations

In conducting questionnaire research, ethical considerations are crucial to ensure that the conduct of this study not only meets scientific standards, but also respects the rights of participants. This study strictly adheres to relevant ethical standards, with a particular emphasis on the confidentiality and anonymity of information, as well as the voluntariness of participants [46-48].

All participants are required to read and agree to an information consent form before starting to fill out the questionnaire, which details the purpose of the survey, expected benefits, potential risks, and the rights of the participants. The consent letter emphasizes that participation in this study is entirely based on voluntary principles, and participants have the right to withdraw from the study at any time without any adverse consequences. To protect the privacy of participants, all collected data is processed anonymously and does not contain any personally identifiable information. When designing the questionnaire, avoid using sensitive questions and ensure that the data is stored on a password protected secure server. Only authorized researchers can access this data and it is only for research purposes. The data analysis in this study also adheres to the principle of anonymity. When reporting research results, no personal information would be disclosed, and all data are presented in

summary form to ensure that no individual's identity can be inferred from the results. In order to further uphold ethical standards, this study has been approved by the corresponding ethics review committee. The research also promises to strictly comply with all ethical review requirements, regularly monitor the research process, and ensure continuous compliance with ethical standards.

Through these measures, this study aims to ensure that high ethical standards are maintained, thereby not only enhancing the scientific validity and credibility of the research, but also safeguarding the interests and rights of participants, ensuring the overall quality and effectiveness of the research.

3.5 Anticipated Issues and Measures

During the questionnaire survey process of this study, it is expected to encounter some challenges that may affect the efficiency and quality of data collection. In response to these potential issues, this thesis has developed corresponding response strategies to ensure the smooth progress of the research and the reliability of the results [49].

A common problem is low response rate, which may lead to sample bias, thereby affecting the representativeness and accuracy of research results. To address this issue, this thesis adopts various strategies to increase participation. For example, promoting the importance and purpose of research through multiple channels can increase the interest and motivation of potential participants. In addition, this thesis also plans to provide small incentives, such as lucky draws or small gifts, to encourage more people to complete the questionnaire. The quality of data is also a challenge that needs attention. There may be participants filling out questionnaires at will or misunderstanding questions, resulting in inaccurate data. Therefore, validation questions are included in the questionnaire design to detect inconsistent or untrue answers. At the same time, the questionnaire underwent pre-testing to evaluate the clarity of the questions and whether they are easily misunderstood. The questionnaire content would be adjusted based on feedback to ensure the accuracy and understanding of the question expression. Technical issues may also affect the process of filling out online questionnaires. Unstable network connections or platform failures may result in data loss or participants being unable to complete the questionnaire. To reduce such risks, the research chose a stable and reliable online survey platform. There may be questions that may affect the understanding and answering of the questionnaire due to cultural differences or personal backgrounds. To address this challenge, the questionnaire uses simple and universally understandable language, taking into account the potential differences among participants from different cultural backgrounds. When necessary, the research also provided multilingual versions of the questionnaire to accommodate participants from different language backgrounds.

Through these comprehensive strategies, this study aims to overcome potential challenges to the greatest extent possible, ensure the smooth progress of the data collection process, as well as the quality and reliability of the collected data, thereby providing a solid foundation for subsequent data analysis and research conclusions. The relevant survey questionnaire is attached in the appendix.

Chapter 4 Results

4.1 Basic Information of Participants

This study collected a total of 100 valid questionnaires, and the basic information of participants obtained from them revealed some key demographic characteristics. In terms of gender, participants were slightly more male than female, accounting for 52%, indicating a relatively balanced gender distribution in the survey. This distribution helps to ensure that data collected from different gender perspectives is more comprehensive and improves the universal applicability of research results. The age structure shows that young adults aged 26 to 35 are the largest group of participants, accounting for 30%, followed by the age group aged 36 to 45, accounting for 25%. This indicates that the survey mainly attracted the participation of middle-aged and young professionals in the workplace, possibly because this age group is more likely to be exposed to and understand the application of AI technology. The high proportion of young participants may also affect the survey results, leading to a higher acceptance of new technologies and environmental awareness, as shown in Figures 4.1 and 4.2.

Figure 4. 1 Gender distribution

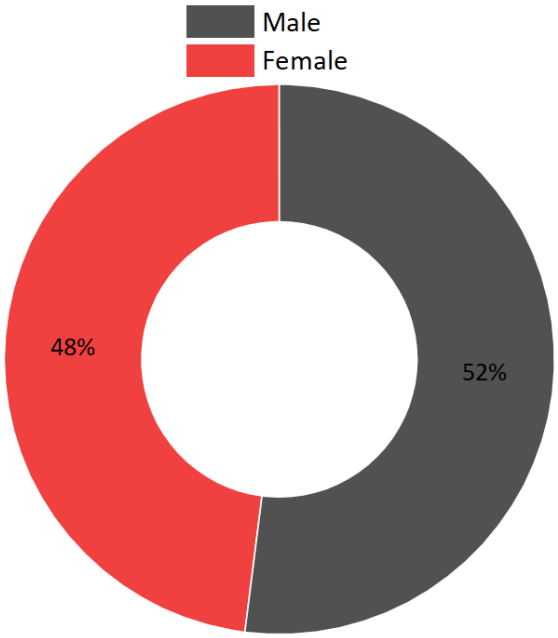
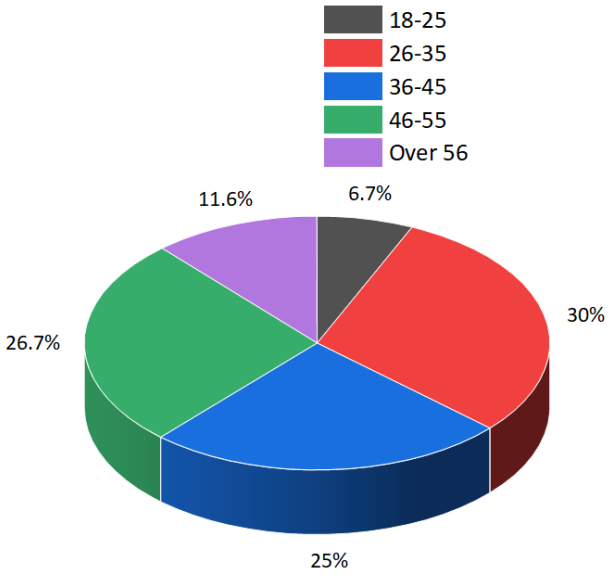


Figure 4. 2 Age distribution



In terms of education, the proportion of participants with a bachelor's degree is the highest, reaching 40%, indicating the interest and enthusiasm of the group with higher education levels towards such surveys. Participants with higher education typically have better comprehension abilities and more complex thinking patterns, which may enable them to provide deeper insights when answering questions about technology and the environment. According to occupational data, the proportion of participants in the fields of information technology and research and development is relatively high, accounting for 25% and 20% respectively. This discovery is in line with expectations, as professionals in these fields may have a more direct understanding and interest in the environmental impact of AI technology. In addition, there are also many participants in the manufacturing and education industries, which may reflect their practical attention and potential applications in exploring AI technology to reduce carbon emissions, as shown in Figures 4.3 and 4.4.

Figure 4. 3 Educational distribution

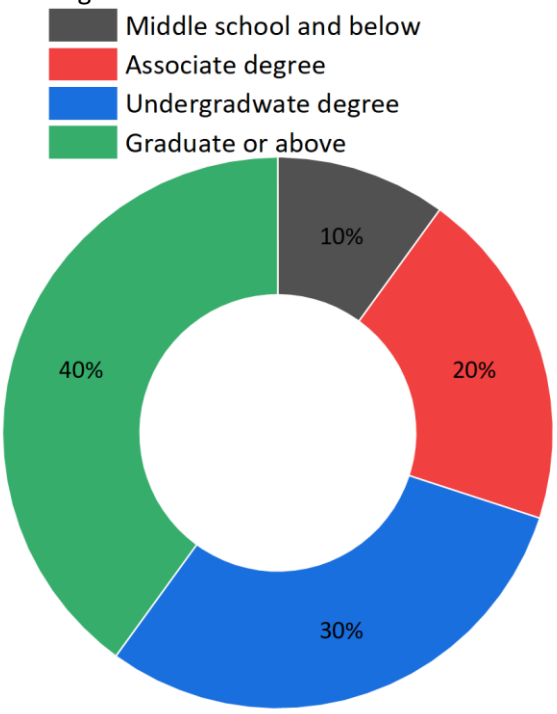
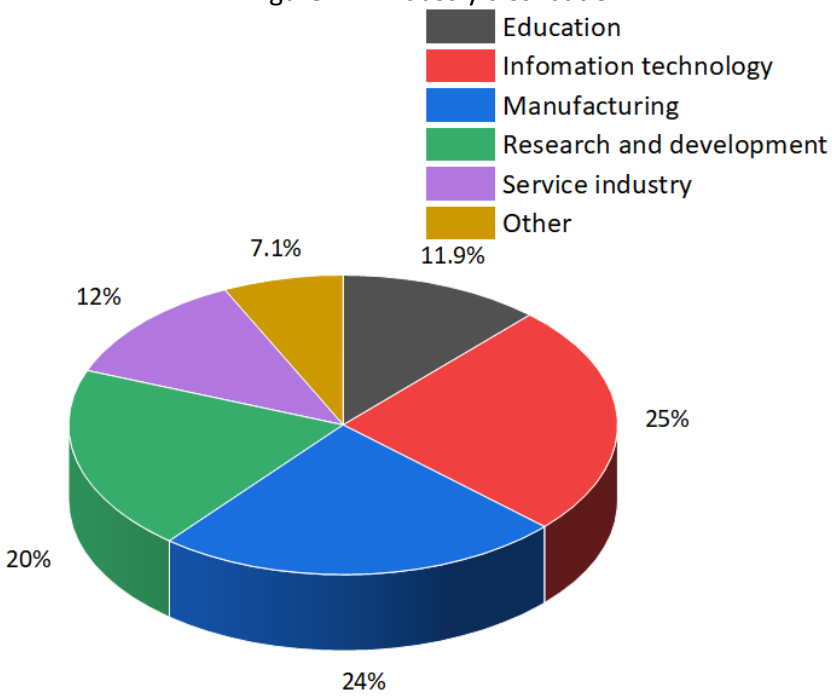


Figure 4. 4 Industry distribution



The Table 4.1 summarizes participants' characteristics.

Table 4. 1 Participant description

Characteristics	Distribution
Gender	Male: 52% Female: 48%
Age	18-25: 6.7% 26-35: 30% 36-45: 25% 46-55: 26.7% Over 56: 11.6%
Educational	Middle school and below: 10% Associate degree: 20% Undergraduate degree: 30% Graduate degree: 40%
Industry	Education: 11.9% Information technology: 25% Manufacturing: 24% Research and development: 20%, Service industry: 12% Other: 7.1%

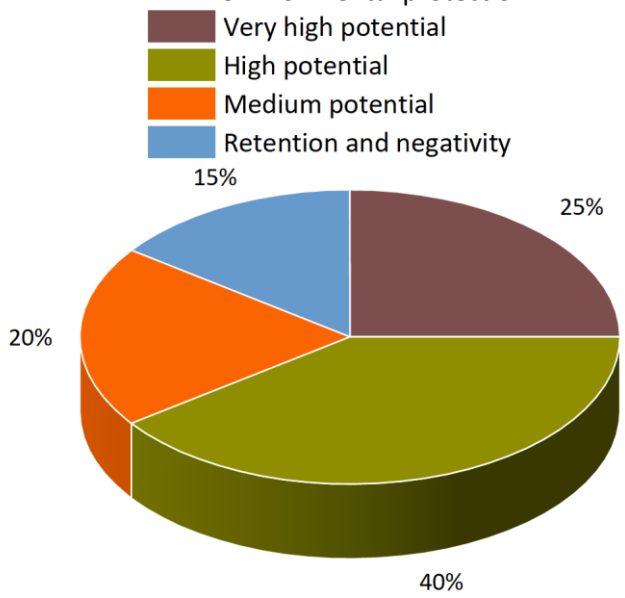
Overall, the demographic data of participants provides a deeper understanding of the survey sample, laying a solid foundation for further analysis on how to effectively utilize AI technology to achieve the goal of carbon emission reduction. The diversity of these data helps to enhance the reliability and generalizability of research results, providing valuable insights for future policy making and technology development.

4.2 Understanding of the Carbon Emission Reduction Potential of AI Technology

By analyzing the questionnaire results in detail, we are able to gain a deeper understanding of how the public views the application and effectiveness of AI technology in the field of environmental protection. Regarding the overall perception of participants towards the potential of AI technology to reduce carbon emissions, the results showed that 25% of participants believed that AI technology had very

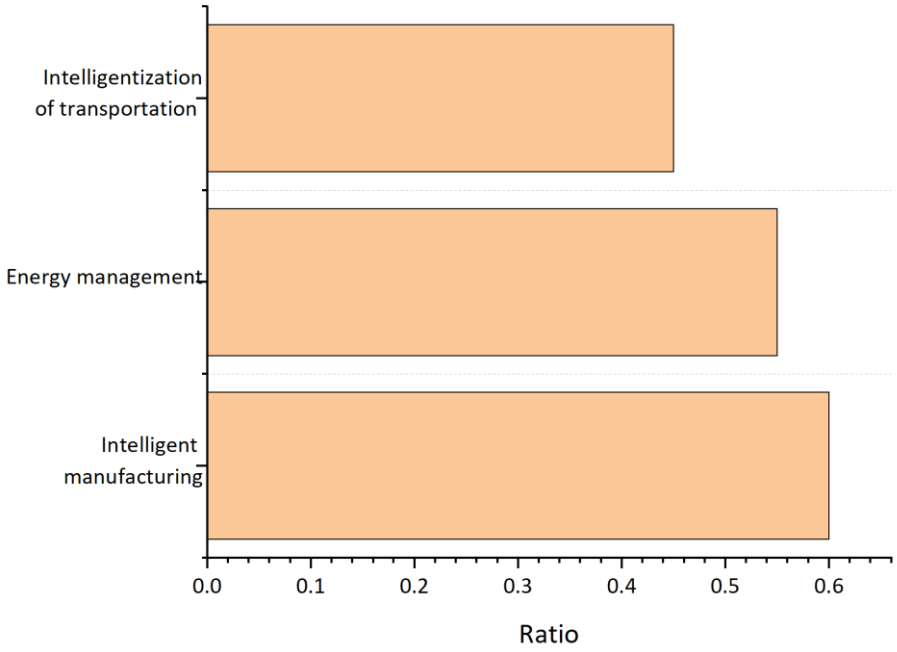
high carbon reduction potential, 40% of participants believed that the potential was high, 20% of participants believed that the potential was moderate, and the remaining 35%（20%+15%） of participants held a reserved or negative view. This distribution indicates that the majority of participants have a positive attitude towards AI technology in environmental protection, believing that it can effectively help reduce carbon emissions.

Figure 4. 5 Public opinion on the application and effectiveness of AI technology in the field of environmental protection



In exploring the field of AI applications, participants were asked which specific AI applications are most likely to effectively reduce carbon emissions. Survey data shows that the majority of participants believe that intelligent manufacturing (60%) and energy management (55%) are the most promising areas, reflecting the important role of AI technology in optimizing production processes and energy use. In addition, the intelligentization of transportation systems is also seen by 45% of participants as an effective way to reduce carbon emissions, especially in optimizing traffic flow and reducing ineffective driving.

Figure 4. 6 Which specific AI applications are most likely to be effective in reducing carbon emissions



The relative importance of different AI application fields in reducing carbon emissions can be more intuitively demonstrated through the above figure. This visual data presentation not only helps to understand the comparisons between different fields, but also highlights the areas that the public considers to have the most potential. The research findings in this section clearly indicate that although there are some reservations, most participants believe that AI technology can play a key role in multiple fields, especially in intelligent manufacturing and energy management, to help achieve carbon emissions reduction. These findings provide a foundation for further technological development and policy formulation, pointing to areas where the public expects AI technology to play a greater role.

4.3 Actual Environmental Protection Effects of AI Technology

Concentrate on analyzing the environmental effects of AI technology reported by participants in their actual work or life, as well as the main challenges and obstacles they face.

4.3.1 Environmental Protection Effect Statistics

Through a questionnaire survey, we collected data to evaluate the contribution of AI technology to environmental protection in practical applications. According to the survey results, the relevant results are as follows:

Reduce resource waste: Approximately 65% of participants stated that through the application of AI technology, their organizations can use resources more effectively, such as reducing energy and raw material consumption through intelligent scheduling systems; Optimizing energy use: About 70% of participants believe that AI technology has helped them optimize energy use, especially in energy management and automation systems, effectively reducing energy consumption and carbon emissions; Improving production efficiency: Approximately 60% of participants reported that AI technology significantly improves production efficiency through automation and precise control of production processes, indirectly reducing environmental pressure.

4.3.2 Challenges and Obstacles

Despite the enormous potential of AI technology in the field of environmental protection, participants also reported some major challenges and obstacles encountered in practical operations:

Cost issue: About 40% of participants pointed out that high initial investment and maintenance costs are the main obstacles to adopting AI technology, especially for small and medium-sized enterprises; Immature technology: About 30% of participants reported that existing AI solutions still need to be improved in terms of stability and reliability, and sometimes immature technology can affect the overall effectiveness; Lack of professional talents: About 25% of participants stated that the lack of professional talents capable of effectively managing and operating AI systems is an important issue, which limits the widespread application of technology; Regulatory limitations: Approximately 5% of participants believe that current regulations and policies have not kept up with the pace of technological development, which has become another obstacle to promoting the use of AI technology.

Overall, the above content not only reveals the positive effects of AI technology in practical environments, but also points out the specific challenges to achieving these effects. These findings provide valuable information for future technological improvements, policy formulation, and resource allocation.

4.4 Impact of Environmental Regulations

In this study, we focused on analyzing the support of participants for strengthening environmental regulations to promote the application of AI technology in carbon reduction. The research results in this section demonstrate the public's understanding of the role of policies and regulations in promoting technological development and environmental protection.

4.4.1 Survey Results on Strengthening Environmental Regulations

A key question in the survey questionnaire is whether participants agree to strengthen environmental regulations to promote the application of AI technology in carbon reduction. Data display:

Completely agree: About 45% of participants expressed strong agreement to strengthen environmental regulations, believing that it is an important means to promote technological applications and achieve environmental goals.

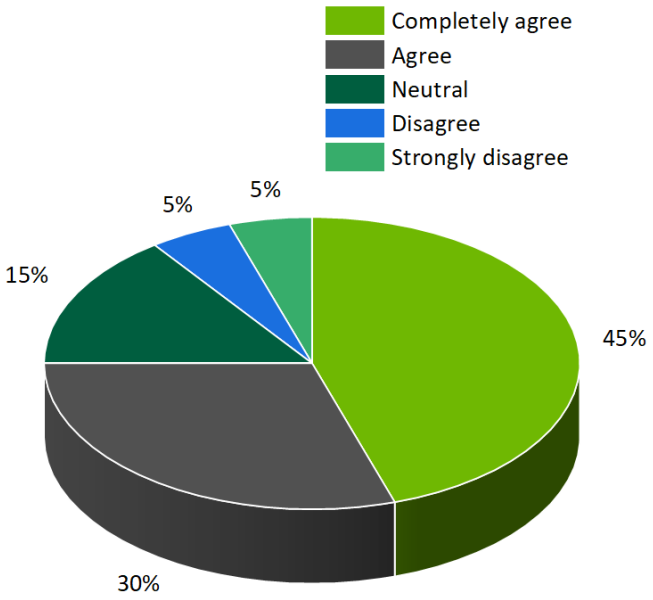
Agree: 30% of participants chose to agree, supporting the adoption of regulations to ensure the environmental direction and sustainability of technology.

Neutral: 15% of participants hold a neutral attitude and may have reservations about the specific effects of regulations.

Disagree: 5% of participants do not agree to strengthen regulations and may believe that excessive regulation may inhibit technological innovation.

Strongly disagree: The remaining 5% strongly disagree, and these individuals may be more inclined towards market driven rather than government intervention.

Figure 4. 7 Survey results on whether the public agrees to strengthen environmental regulations to promote the application of AI technology in carbon reduction



In addition, the reasons for supporting and opposing strengthened regulation can be further analyzed through open-ended responses to gain deeper insights.

4.4.2 Insights from Open-Ended Responses on Regulatory Impact

In the open-ended questions section of the questionnaire, we asked participants for their specific opinions and suggestions on strengthening environmental regulations. Many participants emphasized that reasonable regulations can:

Promote the research and application of clean energy and environmental protection technologies; Set clear environmental standards for enterprises and promote the low-carbon transformation of industries; Enhance public awareness of the importance of environmental protection and enhance social responsibility through education and publicity.

However, some participants expressed concerns about excessive regulation, believing that it may cause the following problems:

Suppress the innovation drive of enterprises; Increasing operational costs for enterprises, especially those that may cause significant pressure on small and medium-sized enterprises; Inconsistent enforcement of regulations may lead to market chaos.

Through these data and analysis, the research results not only reflect the widespread public support for environmental regulations, but also point out key issues that need to be balanced when formulating and implementing environmental regulations. This provides a basis for formulating more effective policies and also provides a direction for in-depth exploration in future research.

4.5 Public Suggestions for AI Technology in Carbon Reduction

The open-ended responses collected from the questionnaire showed that participants provided various suggestions on how to use AI technology to achieve more effective carbon emission reduction. These suggestions can be roughly classified into the following main areas:

1.Technological innovation and research and development:

Many participants emphasized the need to increase investment in research and development of environmental protection technologies related to AI, especially in areas such as energy efficiency, renewable energy management, and intelligent manufacturing. They suggest that the government and private sector should increase financial support to promote innovation and commercialization of related technologies. "We must increase investment in the research and commercialization of AI environmental protection technologies, such as improving energy efficiency and optimizing renewable energy management" — Survey participant A, Age: 35, Occupation: Environmental Engineer.

2.Policy support and incentive measures:

Participants suggest that the government should develop more attractive policies and incentives, such as tax incentives, subsidies, etc., to encourage businesses and individuals to adopt AI technology to reduce carbon emissions. In addition, it is recommended to establish a clearer policy framework to guide and regulate the application of AI technology in the field of environmental protection. "The government should provide more tax breaks and subsidies to attract companies and individuals to adopt AI to reduce carbon emissions. A clear policy framework is crucial for guiding the application of AI technology" — Survey participant B, Age: 42, Occupation: Policy Analyst.

3.Education and public awareness enhancement:

Many participants pointed out that increasing public awareness of carbon reduction and the potential of AI is crucial. They propose to enhance public understanding of how these technologies can help protect the environment through educational programs, workshops, and media promotion. "It is crucial to enhance public awareness of the potential of AI in environmental protection through educational programs and media promotion" —— Survey participant C, Age: 29, Occupation: Educator.

4.Cross industry cooperation:

Some suggestions involve strengthening cooperation between different industries, such as the energy, manufacturing, and information technology industries, which should jointly research and develop new solutions to achieve the maximum environmental protection effect of AI technology in practical operation. "The cooperation between the energy, manufacturing, and information technology industries is key to achieving the maximum environmental impact of AI technology. We need to jointly develop new solutions" - Survey participant D, Age: 45, Occupation: IT Specialist.

5.Formulation of regulations and standards:

Some participants believe that establishing unified standards and regulations is key to ensuring that AI technology contributes to environmental protection. They suggest that governments and international institutions should establish relevant operational standards and evaluation systems to ensure that the effectiveness of technology applications is measurable and manageable. "Establishing unified standards and regulations is the cornerstone to ensure that AI technology effectively contributes to environmental protection. The government and international institutions should develop operational standards and evaluation systems" — Survey participant E, Age: 37, Occupation: Regulatory Affairs Specialist.

The analysis and organization of these suggestions not only reveal the public's expectations and needs for AI technology in environmental protection, but also point out the current shortcomings in technology application, policy formulation, and social awareness. By integrating these feedbacks research can provide decision-makers with practical action guidelines, helping them respond more

accurately to public expectations and market demands when formulating relevant policies and measures.

The Table 4.2 describes the participants' basic information and the advice they gave from the open-ended questions.

Table 4. 2 Open problem analysis statistical

Classification	Main suggestions	Participant information
Technological innovation and R&D	Increase investment in research and commercialization of AI environmental protection technologies	Environmental engineer, 35
Policy supports and incentives	Develop more tax incentives and subsidies and establish a clear policy framework	Policy analyst, 42
Education and public awareness	Raise public awareness of AI's potential for environmental protection through educational programs and the media	Educator, 29
Cross-industry cooperation	Strengthen cooperation in the energy, manufacturing and IT sectors	IT specialist, 45
Formulate regulations and standards	Establish uniform standards and regulations to ensure the contribution of AI technology to environmental protection	Regulatory affairs specialist, 37

4.6 Comprehensive Analysis and Summary

This study explores the correlation between the collected data and the main findings and trends derived from the questionnaire results. The focus was on analyzing the relationship between the background information of participants—such as age, occupation, and their perception of the carbon reduction potential of AI technology—and statistical validation was conducted on these data. In line with the literature reviewed in Chapter 2, where scholars have pointed out both the potential benefits and the risks of AI technology in environmental applications, our analysis finds that demographic factors play a significant role in shaping perceptions of AI’s effectiveness.

Age and technological cognition: Data shows that young participants (especially those within the age range of 26–35) tend to have a more positive attitude towards the potential of AI technology in

reducing carbon emissions. This observation is consistent with earlier studies that emphasize how the younger generation's higher technological acceptance and greater environmental awareness contribute to their favorable evaluation of innovative solutions. These studies also suggest that young people are generally more open to integrating new technologies into sustainability practices.

Career and Technical Assessment: From a professional perspective, individuals working in fields such as information technology and research and development have provided higher evaluations of AI's environmental potential. This finding echoes the literature in Chapter 2 where research by Gao & Peng and studies on sector-specific AI applications indicate that professionals with a strong technological background are more confident in the benefits and environmental efficiencies offered by AI. Their familiarity with the technical challenges—such as high energy consumption and the need for optimized algorithms—enhances their overall positive assessment.

Education level and environmental awareness: The data also reveals that participants with higher education levels are more likely to recognize the environmental effects of AI technology. This supports findings from the literature review, where scholars like Lee & Mackey and Leone et al. argue that higher educational attainment is linked to a better understanding of both the advantages and the limitations of advanced technologies. Such a background facilitates a more nuanced awareness of how AI can be harnessed for sustainable development while acknowledging its inherent challenges, including technological risks and potential inequalities.

In summary, the comprehensive analysis highlights several key research findings:

General recognition of technological potential: Most participants believe that AI technology holds significant promise for reducing carbon emissions, especially in areas such as intelligent manufacturing and energy management. This aligns with the previous research that underscores AI's dual role in enhancing efficiency and managing environmental risks.

Policy and educational needs: The study emphasizes the necessity of strengthening policy support and public education to improve the acceptance and implementation effectiveness of technology. This is supported by findings in Chapter 2 which indicate that effective policy frameworks and enhanced public awareness are critical for realizing AI's full potential in environmental protection.

The importance of cooperation and standardization: Enhancing industry cooperation and establishing unified standards are considered key factors in realizing technological potential—a point also stressed in the literature review.

The correlation between technological acceptance and demographic characteristics: The data reveal that younger individuals and professionals in technology-related fields show higher acceptance and expectations for AI technology. These observations are consistent with earlier research that highlights the role of education and professional background in understanding and leveraging AI for sustainable development.

Finally, the research findings of this thesis are expected not only to provide direction for future technological development and policy formulation but also to offer data support and a theoretical foundation for further academic research and practical applications. Through this comprehensive data analysis and discussion—reinforced by insights from the literature in Chapter 2—we can better understand the application prospects and challenges of AI technology in environmental protection, providing valuable insights for decision-makers and practitioners in related fields.

Chapter 5 Discussion

5.1 The Current Situation and Prospects of the Application Of AI

Technology in environmental protection is gradually becoming an important force in promoting sustainable development. Through intelligent management and optimized resource utilization, AI technology has significantly reduced carbon emissions in multiple aspects. For example, intelligent manufacturing can significantly reduce waste by precisely controlling the amounts of materials and energy consumption in the production process; In the field of energy management, AI technology optimizes energy efficiency by predicting and adjusting energy demand and supply, especially in the integration and management of renewable energy, demonstrating its enormous potential. At present, the application of AI in environmental protection has covered multiple aspects, including intelligent monitoring of environmental quality, automatic regulation of energy use, optimization of traffic flow, and reduction of waste production and treatment. These applications not only improve operational efficiency, but also reduce human errors, making environmental actions more precise and efficient.

Looking ahead to the future, with the continuous progress of technology and the gradual reduction of costs, the application prospects of AI in the field of environmental protection are broad. As more innovative AI applications continue to emerge, these technologies can be more deeply integrated into daily life and industrial operations, thereby promoting the process of environmental protection on a broader scale. However, to fully tap into the potential of AI technology in environmental protection, continuous technological innovation and improvement are needed, especially in improving the efficiency and accuracy of algorithms, to ensure that these technologies can maximize their effectiveness in environmental protection. Therefore, from the current situation, the application of AI technology in the field of environmental protection has achieved preliminary results, but to achieve its comprehensive environmental potential, in-depth promotion and support are needed at the three levels of technology, policy, and society.

5.2 Evaluation of the Dual Impact of AI Technology on the Environment

Although AI technology has shown great potential in the field of environmental protection, effectively helping to reduce carbon emissions and optimize resource utilization, its impact on the environment has a dual nature, which has also sparked widespread discussion and attention. In addition to the positive impact, the application of AI technology may also bring some environmental burdens.

The development and operation of AI technology require a significant amount of computing resources, including energy consumption and the use of hardware devices. Especially when training

large ML models, the energy required can be very significant. For example, training an advanced deep learning model may consume electricity equivalent to the annual electricity consumption of hundreds of households. In addition, the heat generated by these calculation processes also requires an additional cooling system, further increasing the use of energy. The rapid development of AI technology has accelerated hardware upgrades, which may exacerbate the problem of electronic waste. Outdated hardware devices are often quickly phased out, but their recycling and processing processes may not be environmentally friendly, and sometimes even lead to the release of harmful substances.

Balancing the environmental application of AI technology with its own environmental costs has become an important aspect in addressing these issues. Research and industry are exploring various methods to mitigate these negative impacts. One method is to improve the energy efficiency of the algorithm by optimizing the model and reducing computational complexity to reduce energy consumption. Another strategy is to use more environmentally friendly energy sources, such as wind or solar, to power data centers. Establishing stricter environmental standards and recycling policies is also an effective way to address the issue of electronic waste. By improving the design standards of electronic products, extending their service life, and strengthening the recycling and disposal of waste equipment, it is possible to effectively reduce the environmental pressure caused by consumption and waste driven by AI technology. Although AI technology has brought many benefits to environmental protection, its own environmental costs cannot be ignored. Through technological innovation and policy adjustments, these advanced technologies can be better utilized while reducing their potential environmental burden and achieving true sustainable development.

5.3 The Importance of Public Awareness and Education

Improving public awareness and educational level is a key factor in promoting the application of AI technology in the field of environmental protection. Although technology itself has the potential to change game rules, no matter how advanced the technology is, if the public and practitioners in related industries lack the necessary knowledge and understanding, the promotion and application of technology would be limited.

The public's understanding of the role of AI technology in the field of environmental protection is relatively limited, which may affect their support for related technologies and policies. For example, if the public does not understand how intelligent systems can help optimize energy use, they may not support government investment or policy-making in this area. Therefore, it is necessary to raise public awareness of the application of AI technology in environmental protection through education and media promotion. Education is also crucial for improving the skills and knowledge level of practitioners.

With the development of AI technology, many new job roles and skill requirements are emerging. Educational institutions need to update their curriculum content, including adding courses on AI and environmental protection, to ensure that future workforce can meet these new roles. In addition, continuing education and training for current practitioners are equally important, which helps them adapt to the rapidly changing technological environment and effectively utilize AI technology to solve environmental problems. Education can also help cultivate innovative thinking and encourage more people to participate in the research and innovation of environmental protection technologies. Innovation is not only at the technical level, but also includes innovation in policies, economic models, and other aspects. With a broad awareness of environmental protection and profound professional knowledge, the public and professionals can actively participate in environmental activities and promote the overall transformation of society towards sustainable development.

In summary, by enhancing the environmental awareness and education of the public and professionals, not only can their understanding of the potential environmental benefits of AI technology be improved, but also the acceptance and application of these technologies can be promoted, ultimately achieving a win-win situation for environmental protection and technological development.

5.4 Comprehensive Recommendations

Based on the results and analysis of this study and in order to more effectively utilize AI technology to promote environmental protection and carbon emission reduction, this thesis proposes the following comprehensive recommendations:

1.Strengthen technological research and innovation:

The government and private sector should increase investment in the research and development of AI technology, especially those projects that directly or indirectly contribute to environmental protection. This includes technologies to improve energy efficiency, optimize resource utilization, and intelligently monitor environmental pollution. At the same time, the development of open-source AI tools and platforms should be encouraged to lower the entry barriers for small and medium-sized enterprises and research institutions and promote the popularization of innovation and applications.

2.Develop and implement supportive policies:

The government should formulate clear policies and regulations to support the application of AI technology in the field of environmental protection. This may include incentives such as tax breaks, subsidies, research and development funding support, as well as regulations to ensure that these technologies are developed and deployed responsibly. In addition, policymakers should consider the

duality of AI technology to ensure that potential negative environmental impacts are prevented while promoting technological development.

3.Improve public education and awareness:

Enhance public awareness of the potential of AI technology in environmental protection through the education system and public media. The educational content should include the basic principles of AI technology, environmental protection application cases, and how individuals and society can participate and benefit from it. In addition, training and continuing education for professionals should be increased to ensure that the labor market can adapt to the demands of these new technologies.

4.Promote cross industry cooperation:

Encourage cooperation between different industries, as well as between academia and industry. By establishing a cooperation platform and sharing mechanism, all parties can share data, resources, and professional knowledge to jointly develop solutions. For example, the energy and information technology industries can collaborate to develop more efficient energy management systems, while the combination of environmental science and computer science can promote the advancement of environmental monitoring and data analysis technologies.

5.Emphasize the sustainability and ethics of technology:

While promoting AI technology, its sustainability and ethics must be taken into consideration. This includes ensuring that technology development and application do not exacerbate social inequality, do not cause irreversible damage to the environment, and do not infringe on personal privacy and rights. Establish strict ethical standards and monitor the implementation of technology in a transparent and responsible manner.

These comprehensive recommendations aim to provide a multidimensional action framework that promotes the effective application of AI technology in the field of environmental protection through technological innovation, policy support, education popularization, and ethical regulation, achieving the dual goals of environmental protection and technological progress.

Chapter 6 Conclusions and Contributions

This study aims to explore the potential and practical effects of AI technology in reducing carbon emissions and promoting environmental protection. By analyzing and discussing questionnaire data, we have summarized the current situation, challenges, and future development directions of AI technology in the field of environmental protection. In addition to identifying key factors that influence AI's role in sustainability, this study provides both theoretical and practical contributions to the field.

First, AI technology demonstrates broad applicability and effectiveness in multiple environmental protection domains, including intelligent manufacturing, energy management, and transportation systems. These applications contribute to optimizing resource utilization and reducing carbon emissions to a certain extent. Most participants expressed a positive attitude toward AI's potential in mitigating environmental impacts and acknowledged its significant prospects for future development. From a practical perspective, these findings provide valuable insights for industries seeking to leverage AI-driven solutions to enhance sustainability. Academically, this study enriches the understanding of AI applications in environmental protection by systematically assessing their effectiveness across different sectors.

Second, despite the notable advantages of AI technology, its development and deployment also present challenges. The operation and maintenance of AI systems require substantial energy and resources, which may offset some of the environmental benefits they generate. Therefore, balancing the trade-off between technological applications' environmental advantages and their resource consumption is a crucial issue for both practitioners and researchers. This study contributes to the academic discourse by highlighting the dual impact of AI and the need for a more holistic assessment framework that considers both the benefits and environmental costs of AI technology. Practically, it underscores the necessity for industries to adopt energy-efficient AI models and invest in sustainable computing solutions.

Third, this study emphasizes the indispensable role of policies and education in promoting AI applications for environmental sustainability. Policymakers play a key role in providing policy incentives, regulatory frameworks, and a conducive market environment that encourages AI-driven environmental solutions. Meanwhile, raising public awareness of AI technology and its environmental potential is equally important in fostering a culture of sustainable technology adoption. Academically, this research advances the discourse on the policy-technology nexus by exploring how regulatory support and public perception shape AI's environmental impact. Practically, it offers actionable recommendations for policymakers and organizations to design initiatives that facilitate AI adoption while ensuring social acceptance and regulatory compliance.

Fourth, cross-industry collaboration is essential in advancing AI applications in environmental protection. Complex environmental challenges require the integration of knowledge, technology, and resources from multiple sectors. By fostering interdisciplinary cooperation, industries can develop innovative AI-driven solutions to address pressing environmental concerns. This study contributes to both academia and practice by highlighting the importance of collaborative efforts in AI research and implementation. From an academic standpoint, it provides a conceptual framework for understanding how different industries can synergistically leverage AI for sustainability. From a practical perspective, it encourages businesses, research institutions, and policymakers to work together in developing cross-sectoral strategies for AI adoption.

Finally, this study presents strategic recommendations for sustainable development, encompassing the strengthening of AI research and development, the formulation of supportive policies, the enhancement of public education, the promotion of cross-industry cooperation, and the emphasis on ethical and sustainable AI deployment. These recommendations serve as a roadmap for decision-makers and practitioners to optimize AI's environmental benefits while ensuring long-term economic, social, and environmental sustainability. Academically, this research contributes to the growing body of literature on AI and sustainability by offering a structured analysis of the opportunities and challenges associated with AI-driven environmental solutions. Practically, it provides concrete guidelines for stakeholders to implement AI technologies in ways that align with sustainability objectives.

Overall, this study underscores the vast potential of AI technology in environmental protection while acknowledging the multiple challenges associated with its practical applications. Future research and practice should continue to explore how AI can be utilized more effectively, ensuring that its development trajectory aligns with the overarching goals of sustainable development. By bridging theoretical insights with real-world applications, this study offers valuable contributions to both academic research and industry practices in the pursuit of AI-driven environmental sustainability.

Chapter 7 Future Work and Research Limitations

Based on this study, we identified several key areas where future research can further explore and deepen the application and impact of AI technology in environmental protection. This study has made significant contributions to both academic research and practical applications by providing empirical data through a comprehensive questionnaire survey and offering an initial theoretical framework for understanding how AI can reduce carbon emissions. These contributions lie in demonstrating the correlation between demographic factors—such as age, education, and professional background—and the perception of AI's environmental potential, as well as in offering practical insights for policymakers and industry practitioners seeking to integrate AI into sustainable development strategies.

1. More In-Depth Technology Impact Assessment: Future research should systematically evaluate the application effectiveness of AI technology in specific environmental protection projects, taking into account long-term environmental, economic, and social impacts. This includes exploring best practices as well as analyzing failure cases in diverse environmental fields. By doing so, researchers can better understand the conditions under which AI is most effective, as well as the factors that limit its performance. Such in-depth assessment can build upon the empirical foundations provided by our survey and contribute to refining theoretical models of technology adoption and its environmental impacts.

2. Comprehensive Research on Technology and Strategy: Research should focus on the integration and synergistic application of AI with other emerging environmental technologies—such as the Internet of Things and big data analytics—to determine how these combined approaches can enhance overall environmental protection. This direction calls for a detailed analysis of policy frameworks across different countries and regions to evaluate how regulatory environments influence the deployment of AI. Based on our study's preliminary findings, future investigations should propose specific policy improvements and strategic recommendations that align technological innovation with sustainable development goals.

3. Public Acceptance and Behavior Research: Another vital direction is to examine public attitudes and acceptance towards AI applications in environmental protection. This research should particularly consider the influence of cultural and economic differences, and investigate how enhanced public awareness and educational initiatives can foster broader support. Our findings indicate that demographic factors significantly shape perceptions; therefore, further research should explore tailored educational programs and social promotion strategies that can bridge knowledge gaps and improve public engagement with AI-driven environmental initiatives.

4. Exploration of Ethical and Legal Issues: Given the complex challenges of data privacy, algorithm transparency, and fairness inherent in AI applications, future research should conduct in-depth studies

on the ethical and legal implications associated with using AI for environmental protection. This includes the development of international legal frameworks and standardized guidelines that ensure responsible and sustainable application of AI technology. Addressing these issues is crucial for both protecting individual rights and establishing public trust in new technological solutions.

5. Innovation of Interdisciplinary Cooperation Models: There is also a pressing need to develop new research methods and collaborative models that promote the interdisciplinary integration of environmental science, computer science, sociology, and other related fields. Establishing collaborative platforms between industry and academia can facilitate the joint development of innovative solutions that address environmental challenges. By drawing on diverse perspectives, future research can better capture the multifaceted impact of AI technology and propose robust strategies that are adaptable across various contexts.

While this study provides a valuable foundation, it also faces certain methodological limitations. The research relies primarily on questionnaire surveys, which may introduce sample bias—especially given the predominance of responses from young professionals—thereby limiting the generalizability of the results. Additionally, low response rates can affect both the representativeness and the statistical accuracy of the findings. Another significant limitation lies in the evaluation of the environmental costs associated with AI technology. Although AI is widely recognized as a tool for optimizing resource utilization and reducing energy consumption, the operational energy demands and potential exacerbation of electronic waste were not comprehensively addressed. These challenges suggest the need for more diversified research methods—such as case studies, field experiments, and longitudinal studies—to validate and extend our initial findings.

To overcome these limitations and enhance the robustness of future studies, we propose the following recommendations:

Expand Sample Diversity: Broaden the geographic and cultural scope of research to include a more diverse set of participants, thereby increasing the relevance and generalizability of the results.

Integrate Multiple Research Methods: Combine quantitative surveys with qualitative methods (e.g., interviews and case studies) and technological impact assessments to capture both the benefits and the environmental costs of AI implementations.

Deepen Policy Analysis: Conduct more granular investigations into how specific policy factors affect AI deployment in environmental protection, and develop detailed recommendations for creating supportive regulatory frameworks.

Focus on Long-Term Impact Studies: Initiate longitudinal studies to monitor the ongoing impact of AI technology on environmental outcomes, allowing for an assessment of both short-term benefits and long-term sustainability.

Promote Interdisciplinary Collaboration: Develop platforms and collaborative networks that encourage cross-disciplinary research, ensuring that technological innovations are examined from multiple angles, including economic, ethical, and social perspectives.

In summary, while this study lays an important foundation for understanding the potential of AI technology in reducing carbon emissions and protecting the environment, it also highlights the necessity of addressing methodological challenges and expanding the scope of future research. By systematically evaluating technology impacts, enhancing strategic policy integration, improving public engagement, rigorously addressing ethical issues, and fostering interdisciplinary cooperation, future research can build on our findings to offer more comprehensive insights and practical solutions. This not only advances academic knowledge but also informs the development of more effective environmental policies and strategies, ultimately contributing to the achievement of sustainable development goals.

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Appendix

Survey questionnaire questions:

Survey questionnaire: The impact of AI technology on carbon emissions

Dear participants, hello!

This survey aims to investigate the application and effectiveness of AI technology in helping to reduce carbon emissions. Your feedback will provide us with important data to help develop more effective policies and technical solutions. This questionnaire will take approximately 5-10 minutes to complete, and all data will be strictly confidential for academic research purposes only.

1、Basic information

1. Gender:

-Male

-Female

-Other

2. Age:

-18-25 years old

-26-35 years old

-36-45 years old

-46-55 years old

-Over 56 years old

3. Highest educational level:

-Middle school and below

-Associate degree

-Undergraduate degree

-Graduate or above

4. Your career field:

-Education industry

-Information technology

-Manufacturing industry

-Service industry

-Research and Development

-Other

2、 Attitude and cognition

5.What do you think is the potential of AI technology in reducing carbon emissions?

-Retention and negativity

-Medium potential

-High potential

-Very high potential

6.Which of the following AI application areas do you think are most effective in reducing carbon emissions? (Multiple options available)

-Intelligent manufacturing

-Energy management

-Transportation system

-Agricultural optimization

-Other

7. What positive environmental effects have AI technology brought to your work or life?

-Reduce resource waste

-Optimize energy use

-Improve production efficiency

-No significant effect

-Other

3、 Environmental impact

8.Do you agree with the following statement: Environmental regulations should be strengthened to promote the application of AI technology in carbon reduction?

-Strongly disagree

-Disagree

-Neutral

-Agree

-Completely agree

9.What is the biggest obstacle you encounter when adopting AI technology?

-Cost issues

-Immature technology

-Lack of professional talents

-Regulatory restrictions

-Other

4、 Conclusion questions

10.Do you have any suggestions or ideas that can help better utilize AI technology to achieve the goal of reducing carbon emissions?

Please fill in your comments or suggestions here.

Thank you for your valuable time and sincere answer!