

**THE MEDIATING EFFECT OF
TECHNOLOGICAL INNOVATION ON THE
IMPACT OF POLICY FACTORS, MARKET
INTERVENTION, AND INDUSTRIAL
AGGLOMERATION ON ENERGY EFFICIENCY
IN THE ERDOS ZERO-CARBON
INDUSTRIAL PARK, INNER MONGOLIA, CHINA**

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UNIVERSITI SAINS MALAYSIA

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by

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LIST OF ABBREVIATIONS

CT	Carbon tax
CFA	Confirmatory factor analysis
EE	Energy efficiency
EEDs	Energy efficiency drivers
EFA	Exploratory factor analysis
ESM	Equation structural modeling
EZCIP	Erds Zero Carbon Industrial Park
HC	Human capital
IA	Industrial agglomeration
IP	Industrial Park
IPCS	Industrial park construction standards
IV	Independent variables
MI	Market intervention
PF	Policy factor
PI	Policy instruments
SFA	Stochastic frontier analysis
TF	Technological factor
TFEE	Total factor energy efficiency
TI	Technological innovation
ZCIP	Zero Carbon Industrial Park
ZCIPEE	Zero Carbon Industrial Park energy efficiency

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APPENDIX A QUESTIONNAIRE

KESAN PERANTARA INOVASI TEKNOLOGI TERHADAP IMPAK
FAKTOR POLISI INTERVENSI PASARAN DAN
AGLOMERASI INDUSTRI TERHADAP KECEKAPAN TENAGA DI ERDOS
ZERO-CARBON INDUSTRIAL PARK, INNER MONGOLIA, CHINA

ABSTRAK

Selaras dengan komitmen China mencapai neutraliti karbon menjelang 2060, kajian ini meneliti Taman Perindustrian Karbon Sifar Erdos (EZCIP) bagi memahami peranan pemacu utama—faktor dasar (PF), pengaglomeratan industri (IA), dan intervensi pasaran (MI)—dalam meningkatkan kecekapan tenaga (EE) menerusi pengantaraan inovasi teknologi (TI). Kajian ini menggunakan pendekatan kuantitatif rentas keratan dan Pemodelan Persamaan Berstruktur (SEM) bagi menganalisis data yang diperoleh melalui persampelan rawak terhadap syarikat teknologi tinggi dan tenaga boleh baharu di EZCIP. Hasil kajian menunjukkan PF, IA dan MI mempunyai kesan langsung signifikan terhadap EE, manakala TI bertindak sebagai pengantara kritikal yang memperkukuh pengaruh intervensi luaran serta memudahkan penerapan teknologi penjimatan tenaga. Kajian ini menegaskan integrasi sokongan dasar, pengklusteran industri dan mekanisme pasaran mampu menghasilkan kitaran inovasi dan pengoptimuman tenaga lestari. Sebagai antara kajian terawal mengenai EE dalam konteks Taman Perindustrian Karbon Sifar di China, dapatan ini memperluas wacana sedia ada dengan memposisikan TI sebagai pengantara utama dalam menterjemahkan pemacu luaran kepada hasil mampan. Di samping itu, kajian ini menyediakan cadangan praktikal kepada penggubal dasar dan penggiat industri, termasuk strategi meniru kejayaan taman perindustrian konvensional, seterusnya menyumbang kepada peralihan global ke arah pertumbuhan industri rendah karbon mampan.

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ABSTRACT

In alignment with China's commitment to achieving carbon neutrality by 2060, this study examines the Erdos Zero-Carbon Industrial Park (EZCIP) to investigate how policy factors (PF), industrial agglomeration (IA), and market interventions (MI) influence energy efficiency (EE) through the mediating role of technological innovation (TI). Using a cross-sectional quantitative approach and Structural Equation Modeling (SEM), data were collected through surveys of high-tech and renewable energy companies within EZCIP. The findings indicate that policy factors, industrial agglomeration, and market interventions significantly enhance energy efficiency by promoting technological innovation. The study also emphasizes that the integration of policy support, industry clustering, and market mechanisms creates a sustainable cycle of innovation and energy optimization. As one of the first studies focusing specifically on energy efficiency in zero-carbon industrial parks in China, this research extends existing literature by highlighting technological innovation as a critical mediating variable, bridging external drivers and energy efficiency outcomes. Furthermore, this research provides valuable recommendations to policymakers and industry practitioners, offering practical strategies to replicate successes from conventional industrial parks, thereby contributing to the global transition towards low-carbon, sustainable industrial growth.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In the past two years, the effects of global climate change have become increasingly apparent, with more frequent occurrences of extreme weather phenomena (UN, 2022). According to the WMO's Global Climate Status 2022 report, the years 2015 to 2022 are the eight warmest on record (WMO, 2023). Global average temperature in 2021 is about 1.11 degrees Celsius above the world average temperature between 1850 and 1900 ("pre-industrial average") (WMO, 2021). This outcome poses a significant threat to human survival and development as a consequence of the increase in greenhouse gas emissions that has led to global warming (UN, 2022). In 2022, persistent drought in East Africa, record rainfall in Pakistan, and record heatwaves in China and Europe impacted tens of millions of people, exacerbated food insecurity, facilitated mass migration, and caused billions of dollars in loss and damage (WMO, 2023). In addition, the global energy market has experienced significant volatility due to the impact of the new Crown Pneumonia epidemics, the Ukraine crisis, and other geopolitical situations. Energy security and affordability have become topics of general concern. The energy transition faces both short-term and long-term challenges, highlighting its complexity and systemic nature (IEA, 2023). The greater threat is the long-term development of a 40% to 70% of the planet's species would be at risk of extinction if carbon dioxide emissions resulted in

a 4°C rise in average global temperature (IPCC, 2007). The climate crisis, the development of renewable energy sources, and the Sustainable Development Goals required attention. The Covid-19 pandemic had a significant impact on energy demand in 2020, resulting in a 5.2% decrease in global CO₂ emissions (IEA, 2022). But Global CO₂ emissions from energy combustion and industrial processes rebounded in 2021 to reach their highest ever annual level. A 6% increase from 2020 pushed emissions to 36.3 Gt (IEA, 2022). Significant obstacles persist in addressing the climate crisis and the energy transition, with many countries continuing to rely on traditional energy sources to meet rising energy demand (Jahanger et al., 2023). Global temperature rise could reach 2.8°C by the end of the century, says IPCC's Sixth Assessment Report (IPCC, 2023). If the 1.5°C temperature rise target is to be met, global greenhouse gas emissions must peak by 2025, decline by about 43% from peak levels by 2030, and reach net negative carbon dioxide emissions by 2050 (IPCC, 2023 ; WMO, 2023). To achieve these goals, countries need to accelerate the energy transition and take stronger measures to combat climate change.

In 2020, the top seven emitters will account for 50% percent of the world's carbon emissions from greenhouse gases (UN 2019). Therefore, industrial nations have established reduction targets for greenhouse gas emissions (UN, 2020) In response to climate change issues, countries worldwide are shifting their development paths, actively formulating low-carbon development strategies and roadmaps, and accelerating the development and low-carbon technologies to occupy

the high ground of future international competition and lead the new direction of world economic development (Wu et al., 2013). The industrial sectors are notably energy-intensive and account for 40% of the global energy use. Increased carbon emissions caused by energy consumption have resulted in serious environmental problems, including global warming (Wang et al., 2011; Zhang et al., 2015).

As the world's greatest carbon emitter, China must assume a significant role in addressing climate change (Pan et al., 2021). China has been an active participant in the global effort to combat climate change and has pledged to reach its CO₂ emissions climax by 2030 (Yu et al., 2017). According to the China Climate Pathway report, China's carbon emissions mostly come from five key industries: energy, industry, transportation, construction, and agriculture, with the energy and industrial sectors accounting for more than 80% of carbon emissions (IPCC, 2020). IPs are a significant source of carbon emissions and pollutant emissions, and they also play an essential role in mitigating climate change (Yu, et al., 2017).

According to the Ministry of Ecology and Environment of the People's Republic of China, China has made green and low-carbon development an important part of its national economic and social development plan (MEEPRC, 2021). It has built a "1+N" policy system to achieve sustainable development in industry, rural areas, transportation and other areas (MEEPRC, 2022). By 2025, the State Council's designated objectives include the initial formation of a green, low-carbon, circular economy and a significant improvement in energy use efficiency in key industries, with energy consumption per unit of GDP decreasing by 18% compared to 2020

(State Council, 2021). China's CO₂ emissions are expected to peak by 2030 and become carbon neutral by 2060 (CEWC, 2020). A zero-carbon transition in the industrial sector is an effective method for China to combat climate change and can assist the country in reaching its carbon neutrality objective (CCEEE, 2021). Due to market competitiveness and high-quality development, the industry must transition to a low- or zero-carbon economy (CaiXin Insight, 2022).

1.2 Problem Statement

Further improving EE for quality development will undoubtedly result in extensive and profound economic and social change. As a result of the magnitude of China's Sustained focus on improving EE, there are still obstacles to achieving carbon neutrality, despite the fact that China possesses the fundamental conditions for achieving carbon neutrality (Liu et al., 2020). This includes the constraints of economic development needs and energy conservation and emission reduction, the main challenges confronting the energy transition, and the shift in societal perceptions and awareness required to achieve carbon neutrality (Chen et al., 2023). This demonstrates that carbon depletion and carbon neutrality are global concerns. This reinforces the fact that carbon peaking and carbon neutrality are global, long-term endeavours that are not only an environmental or energy issue, or a purely technological issue, but also a global development issue that requires a community-wide effort to address (IMARPG, 2021).

China's carbon emissions are enormous, and achieving a zero-carbon industrial system will present a formidable challenge (Wang, 2022). Few research studies have

been conducted on the carbon emission development paths of IPs due to the large number and variety of IPs in China and their various phases of development (CCEEE 2021). Currently, these IPs confront a number of challenges, including an excessive number and fragmentation, a dearth of distinctive characteristics, and low-value industries (Lyu et al., 2022; Pan et al., 2012).

However, existing research primarily focuses on the macro-level challenges of carbon neutrality, with limited in-depth analysis of how technological innovation (TI) acts as a mediating factor in this process (Su et al., 2023). This study seeks to fill this gap by exploring the role of TI as a mediating variable, providing a more detailed theoretical foundation for the relationship between energy efficiency improvements and carbon neutrality goals. In addition, Chinese EEDs study was conducted relatively late among park enterprises, and only a few of them have launched carbon footprint labels (LCKB, 2018). The existing academic research on new park concepts such as ZCIP is even less mature, development standards and implementation details remain uncertain, and IP transition path should be optimized (Guo et al., 2021; Xie et al., 2021). In the specific literature statistics, worldwide studies is much more active than China's, and despite the fact that China's research literature has increased, the number of citations is low, and the quantity and quality of research must be improved (Wang et al., 2022).

As an essential energy base in northern China, Inner Mongolia Autonomous Region plays a crucial role in China's energy supply (Zhang & Fan, 2022). This province has a unique geographical location, an abundance of natural resources, and

a complex cultural history, making detailed energy and carbon emission studies highly relevant (Wang et al., 2022). However, there is relatively little academic research on energy use and carbon emissions in Inner Mongolia, particularly in the Erdos region (Xu, 2023), which may be attributed to the region's complex geographical environment, unique economic development stage, and cultural differences. For this reason, an in-depth examination of the carbon-neutral development path of industrial parks in Erdos, and how to improve energy efficiency in this region, is of significant academic value and practical importance.

The uniqueness of this study lies in its deepening and innovation of traditional EE research paths. Previous studies have largely treated TI as an independent variable, focusing on the direct effects of green technology innovation on carbon neutrality or EE (Shan et al., 2021 ; Su et al., 2023). However, this study proposes that TI should be treated as a mediating variable, which helps to reveal the complex interaction mechanisms framework of the study. By treating TI as a mediating variable, this research fills a gap in the existing literature and provides a new perspective on the pathways to achieving carbon neutrality (CCEEE 2021 ; Xu, 2023). This innovation offers policymakers a more precise theoretical framework to optimize the coordination between technological innovations of achieving carbon neutrality (Pan et al., 2021).

Understanding the mediating role of TI is essential for EE and carbon neutrality in this study. TI plays a role extends beyond technological improvements to include the multidimensional interaction between policy implementation, industry behavior

transformation, and technological progress (Zaghdoud, 2025). Also, TI as a MV helps us understand how adopted, implemented, and scaled, bridging the gap between improve the total factor energy efficiency and the broader goal of carbon neutrality (Wang et al., 2025). Specifically, TI influences the adoption of energy-saving technologies, accelerates the diffusion of these technologies, and optimizes their application across industries (Wang et al., 2025 ; Zafar et al., 2021). Therefore it makes sense to use TI as a MV in this study will help policymakers, industry leaders, and researchers design and implement more effective strategies for improve EE.

In addition to the above TI, EE in industrial parks is shaped by IA, PFs, and MIs. While these factors individually influence EE, their interactions within ZCIPs remain underexplored. This study examines their combined impact on EE, using the EZCIP as a case study. Government policies are central to the success of energy efficiency initiatives, particularly in China, where state-led interventions play a significant role in shaping industrial transformation (Liu et al., 2020). Regulatory frameworks, subsidies for green technologies, carbon pricing mechanisms, and mandatory energy efficiency targets are critical in fostering an environment conducive to EE improvements (Zeng et al., 2021). While previous studies have explored policy influences on EE, limited research has investigated how these interventions interact with industrial structures and market forces in ZCIPs. This study seeks to address this research gap by examining how PFs influence EE directly and indirectly through their impact on technological innovation.

IA has been widely recognized as a key driver of technological progress and energy efficiency in industrial settings. The clustering of firms within IPs fosters knowledge spillovers, competition, and economies of scale, all of which contribute to enhanced EE (Rosenthal & Strange, 2003; Qin et al., 2023). Prior studies have emphasized that firms within industrial clusters benefit from shared infrastructure and logistical efficiencies, reducing redundant energy consumption (Wang et al., 2018). However, the impact of IA on EE has not been systematically examined within the context of ZCIPs, where advanced technological adoption and low-carbon transitions are actively pursued. Given EZCIP's role as a pilot park, this study aims to fill this gap by analyzing how IA contributes to EE improvements through technology diffusion and collaborative innovation efforts. Similarly, market-based mechanisms such as carbon pricing, emissions trading schemes, and green finance initiatives have gained prominence as tools for enhancing EE in industrial settings (Costantini et al., 2013). MI create financial incentives for firms to invest in cleaner production technologies, thereby complementing regulatory approaches (Shao & Wang, 2022). However, the effectiveness of these interventions is highly context-dependent, varying based on industry structure, firm size, and regional economic conditions (Edziah et al., 2021). Given that EZCIP operates in a policy-driven yet market-oriented framework, this study investigates the role of MI in shaping EE outcomes and its interaction with IA and PFs. By integrating these factors, the study provides a comprehensive analysis of the interplay between IA, PFs, and MI and their collective influence on EE, while also examining the

mediating role of TI in this relationship.

The choice of EZCIP as the focus of this study is grounded in its strategic position as a key site for energy transition and super-pilot of carbon neutrality in northern China (NDRC, 2024). As the first zero-carbon park in the worldwide, which leveraging an advanced innovation system, the park actively explores the application of low-carbon, carbon capture, and negative-carbon technologies, while implementing various innovative measures in carbon emission management and green industry development, providing valuable practical experience for the green transformation of resource-based cities (Ming et al., 2023; NDRC, 2024). EZCIP is not only an important energy hub in the region but also a leader in low-carbon transformation, supported by various policies and technological innovations (OMPG, 2023). The region's unique characteristics make it an ideal case study for carbon-neutral development, offering valuable insights into how similar strategies can be applied to other regions. By deeply analyzing the carbon-neutral development path of EZCIP, this research will contribute to the development of targeted recommendations for energy-efficient IPs and provide practical references for low-carbon transformation across the worldwide.

1.3 Research Questions

This study aims to investigate the impacts of various factors on the drivers of EE. To achieve this, the following research questions have been formulated:

1. What effect does Industrial agglomeration (IA) have on the Drivers of Energy

Efficiency (EE)?

2. What effect does Policy factors (PF) have on the Drivers of Energy Efficiency (EE)?

3. What effect does Market intervention (MI) have on the Drivers of Energy Efficiency (EE)?

4. What effect does Technological innovation (TI) as mediating variables have on the Drivers of Energy Efficiency (EE)?

1.4 Research Objective

The objectives of this research are to identify and analyze the contributions of different factors to the drivers of EE. Specifically, this study seeks to:

1. Identify the contribution of Industrial agglomeration (IA) to Drivers of Energy Efficiency (EE).

By analyzing how IA enhances operational efficiency and reduces energy consumption, this objective aims to provide insights into the role of IA in improving EE in IPs. It will also offer recommendations for integrating automation to achieve energy sustainability.

2. Identify the contribution of Policy factors (PF) to Drivers of Energy Efficiency (EE).

This objective will investigate how Policy factors at different levels influence energy-efficiency efforts and explore how policies can be optimized to support EE initiatives in IPs.

3. Identify the contribution of Market intervention (MI) to Drivers of Energy

Efficiency.

By examining how MI—such as demand for green products and market competition—affect EE initiatives, this objective will highlight the economic drivers for sustainable energy practices within IPs.

4. Identify the contribution of Technological innovation (TI) as a mediating variable to Drivers of Energy Efficiency.

This research will explore how TI acts as a MV, influencing the relationship between other drivers (IA, PF, MF) and EE outcomes. This objective will develop a theoretical framework for understanding TI's role in advancing EE efforts within IPs.

1.5 Scope of Research

The geographic scope of this study is to examine the ZCIP located in Yijinholo Banner, Erdos City, Inner Mongolia Autonomous Region, China. The study takes into account the developmental the background of the region, as well as the fundamental strategy components. Furthermore, EZCIP as the pioneering IP to implement the wind-solar-hydrogen-storage- vehicle model, offers a novel context for investigating the impact of policy, industry clustering, and market dynamics on regional EE (Lv et al., 2020). The study seeks to investigate and uncover the factors that EEDs, taking into account both management and low carbon economic perspectives. Furthermore, the project will gather data by means of a well designed questionnaire targeting the 37 companies inside the EZCIP who possess a comprehensive understanding of EEDs.

1.6 Significance of Study

1.6.1 Conceptual Implications

This study proposes a new conceptual framework to explore how IA, MF, PF, and TF can work together to drive EE and help IP achieve carbon neutrality. The case study chosen for this study is the EZCIP, which, as China's first ZCIP (as of October 2023). This choice is justified by the need to investigate potential enhancements in EE and address the existing dearth of scholarly inquiry on EE within the framework of ZCIP.

1.6.2 Practical Implications

Within the framework of the prevailing worldwide climate catastrophe, this study offers an empirical research foundation and scholarly citation for enhancing EE in the design and advancement of fundamental industrial units across diverse nations. The findings of this research will assist IP developers, policy makers, and park managers in formulating more precise and effective policies and plans to facilitate the sustainable development of IPs. Additionally, these results will serve as a valuable reference for enhancing EE, reducing emissions, and promoting the green transformation of similar industrial parks globally.

1.6.3 Sustainability Implications

This study is valuable in supporting the SDGs, particularly SDG7: Clean Energy and SDG13: Climate Action. This study examines the integration of various factors to enhance EE. It aims to increase awareness regarding the sustainability of industrial activities while offering theoretical support and practical guidelines for implementing green transformation and addressing climate change in the industrial

sector. Additionally, it seeks to foster the harmonious development of environmental, economic, and social sustainability.

1.7 Research Expectations

This study hopes to offer a comprehensive analysis that examines the combined influence of PF, IA, MF, and TF variables on EE. The anticipated outcome of this multidimensional analysis is to enhance the theoretical underpinnings within the realm of energy management and environmental policy.

This study aims to enhance the in-depth understanding of technological factors as mediating variables. Also by exploring in connecting of PF, IA, MF, and EE. The objective is to gain a more comprehensive understanding of these relationships and uncover the underlying mechanisms involved. Furthermore, this research endeavours to offer novel perspectives and theoretical frameworks that can be utilised in future studies.

1.8 Structure of Research

this thesis will be discussed in six chapters:

Chapter 1 (Background): This section introduces the topic of this study, including its background, problem statement, significance, and primary research questions and objectives. This section will provide a comprehensive overview of the topic of this study and provide sufficient background information for readers to comprehend the study while recognising the topic's relationship to climate change and its contribution to sustainable development.

Chapter 2 (Literature Review): In this section, This study will provide a

comprehensive overview of existing research relevant to this research question, including the IVs and DVs MVs and Selection of Case Experimental Area. This section is intended to help the reader review the existing research methods and theoretical foundations while providing a basic understanding and awareness of the current study, and to highlight the gaps and shortcomings in the existing research based on the existing research framework and theory, or the various scenarios and relevant elements of the use of the theory.

Chapter 3 (Research Methodology): This section will describe how the study will explicitly address the proposed research questions, including what type of data will be collected and how it will be collected, as well as how the data will be analysed after collection. How to plainly describe the applicability and feasibility of your method while demonstrating its relevance to the research question.

Chapter 4 (Results): This chapter presents the collected data and the study's findings, including a statistical description of the data, an analysis of the research questions, and the findings.

Chapter 5 (Discussion and Analysis): This chapter interprets the results presented in Chapter 4 and discusses their policy implications. Proposed are policy recommendations for the future development of EZCIP and strategies for achieving carbon neutrality.

Chapter 6 (Conclusion): This chapter summarizes the entire paper, addresses the research questions, evaluates the study's value and limitations, and suggests potential directions for future research. This structure is intended to organize the

paper more clearly, ensuring that the reader can better comprehend the research's purpose, methods, and findings.

1.9 Chapter Summary

This chapter provides an overview of the study design within the framework of climate change and the prevailing issues associated with the climate crisis. It outlines the research problem, research objectives, study limitations, significance, and research expectations. The chapter provides an analysis of the thesis's structure.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter Introduction

This chapter reviews the existing literature related to the key constructs of the study. It begins by introducing the background and basic industrial conditions of the research location, followed by an exploration of the strategies and development pathways employed by industrial parks (IPs) to address climate change and improve the energy efficiency (EE). The chapter further explains the objective of the SDG (Sustainable Development Goal) solution within the context of EE.

The literature review examines the framework that includes one dependent variable (EE) and three independent variables (IVs): the influence of Industrial Agglomeration (IA), Market Intervention (MI), and Policy Factors (PFs) on EE. Additionally, Technological Innovation (TI) is positioned as a mediating variable (MV) within this framework, contributing to the enhancement of EE at the Erdos Zero Carbon Industrial Park (EZCIP).

In conclusion, the chapter presents a conceptual framework and outlines the hypotheses that form the theoretical foundation for the investigation. These components provide the basis for a thorough examination of the factors influencing EE in Erdos.

2.2 Implementing Climate Change Solutions in the Industrial Sector

The industrial sector in China dedicated to IP experiences ongoing challenges

related to energy inefficiency, exhibiting notable disparities across different locations (Guo & Yuan, 2020). The low energy utilization leads to pollution of the natural environment. Therefore, China has committed to achieve peaking carbon and carbon neutrality by 2030 and 2060, respectively (NDRC, 2015). In 2020, China's carbon emissions intensity decreases by 48.4% compared to 2005 and 18.8% compared to 2015, exceeding the 40%~45% reduction target committed to the international community (State Council, 2021). However, carbon emissions from the industrial sector remain high due to the concentration of IPs in the majority of manufacturing industries (Lyu et al., 2022). These manufacturing industries consume 66% of the country's energy consumption (Xu & Lin, 2018). In fact IPs not only contribute more than 50% of the country's industrial output, but also account for 31% of the country's CO₂ emissions (Xu & Lin, 2018). The main reason more than half of China's industries are clustered in thousands of IPs (Yu, 2023). This poses a challenge for environmental sustainability and future net-zero carbon industrial development (Anastasovski, 2023). The State Council issued an action plan to reduce CO₂ emissions per unit of GDP by 60-65% by 2030 compared to 2005, and committed to 2021 Focus on building carbon-neutral demonstration industrial parks (State Council, 2019).

Chen et al. (2010), through the Integrated Resource Strategic Plan (IRSP), demonstrated that enhancing energy efficiency (EE) constitutes an effective strategy for reducing CO₂ emissions. A subsequent report by the U.S. Department of State further corroborated these findings, noting that improvements in EE contributed to a

reduction of approximately 1.5 billion tonnes of CO₂ emissions by 2021. Additionally, Jahanger et al. (2023) confirmed that carbon emissions from industrial growth can be effectively mitigated by EE in IPs in Developed European countries. The twenty-sixth session of the Conference of the Parties to the Climate Change Conference (COP26) asserted that enhancing EE represents a highly efficient and expeditious approach to mitigating carbon emissions. Consequently, the enhancement of EE has garnered significant attention in numerous nations (Wang, 2023).

However, the fact that effectively improve EE still poses numerous obstacles (Feng et al., 2018) and that industrial transformation requires inter-disciplinary cooperation (Zhou, 2023), makes achieving this goal in a short period of time extremely difficult. Particularly The scope of this study focus on the Erdos in Inner Mongolia, a city in western China where it will be much more challenging to reduce emissions than in eastern cities due to the proportion of heavy industries and population. In addition, the impact of government policies on energy/carbon markets and carbon neutral decarbonization strategies is currently ambiguous, and transition strategies for industrial zones are immature (Zhou, 2023). Therefore, this research direction has long-term benefits. Assessing the EE driving force holds significant theoretical and practical significance in the pursuit of sustainable development and economic productivity (Zhou & Li, 2021).

2.3 Erdos Zero Carbon Industrial Park

This part can be divided into three parts which clearly present the background of

the focus of this study. Part one undertakes an examination of the descriptive statistics pertaining to the industrial sectors and carbon emission status in Erdos City. Its objective is to analyse the challenges associated with the industrial structure and emissions in Erdos City. Part two delineates the progression of IPs in China, encompassing the elucidation of low and zero carbon IPs and their significance in China's industrial advancement. The final part provides a comprehensive analysis of the EZCIP, including its development process and outcomes, to enhance the reader's comprehension. Given its status as a coal resource-rich area typical of the region, this area economic growth from 2012 to 2021 is predominately reliant on energy-intensive sectors (Li et al., 2023; Ming et al., 2023; Wang, 2022). Consequently, this part will furnish the fundamental and contextual framework for the investigation aimed at evaluating the EE concerns in EZCIPs and support for this study.

2.3.1 Background of Erdos Industrial Development

Erdos has undergone rapid industrialization in recent years, but still faces the problem of environmental pollution, epitomizing a typical resource-dependent city in China (Li et al., 2023 ; Ming et al., 2023).

According to the Chart 2-1 with the exception of 2020, the industrial added value, output value of the secondary industry, and the proportion of the industrial added value to the output value of the secondary industry have consistently shown an upward trend in terms of total volume in Erdos. The year 2020 has been significantly impacted by the Covid-19, resulting in adverse effects on the local economy and

industrial development (Rugani & Caro, 2020). The value added of the industry experienced a significant increase from 123.953 billion yuan in 2012 to 283.959 billion yuan in 2021, exhibiting an average annual growth rate of 9.6%. The secondary industry's output value witnessed a significant rise from RMB 143.37 billion in 2012 to RMB 307.78 billion in 2021, reflecting an average annual growth rate of 9.1%. The share of industrial added value in the output value of the secondary industry exceeds 80%, and has reached 92.26% in 2021, indicating a gradual and increasing upward trend. The general pattern indicates a gradual increase followed by a more rapid ascent. Hence, the industry in the region plays a crucial role in fostering economic development and serves as the primary catalyst for the region's economic expansion (Andersson & Karpestam, 2013 ; Li et al., 2023).

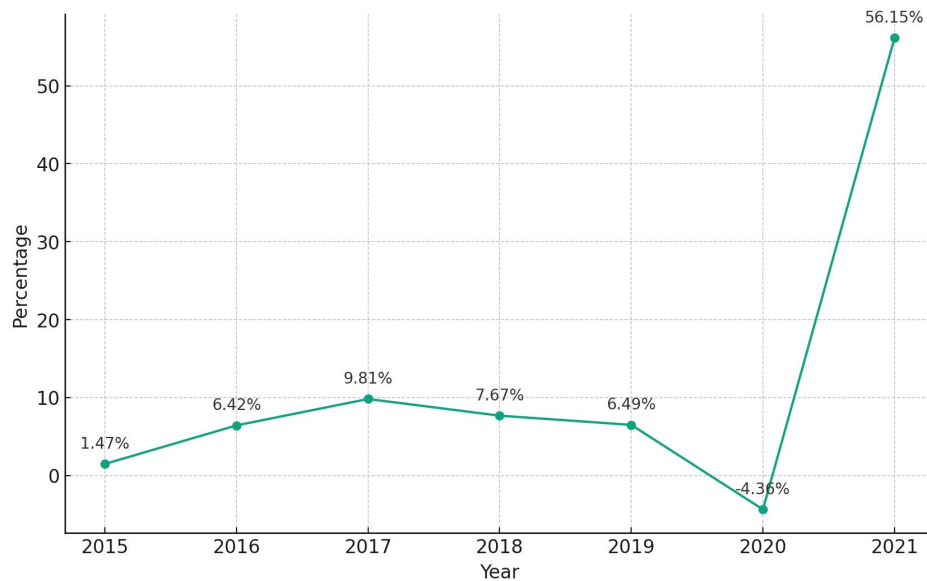


Figure 2-1 Erdos city industrial value-added growth rate chart

(Source: Erdos City Statistical Yearbook (2013-2022))

2.3.1 (a) Earnings from the Erdos Industrial Zone

Variations in primary business revenue and overall profit can serve as reliable indicators of an organization's efficacy (Bao et al., 2022). According to the **Table 2-2** , From 2000 to 2012, the primary revenue of large-scale industrial firms in Erdos City consistently increased and maintained a high level. But between 2013 and 2020, the main business revenue of industrial businesses above a certain size gradually decreased and displayed a downward trend, with a negative growth rate, but there was a small resurgence in 2016. The overall trend in terms of total profit and its growth rate is generally aligned with the main business income. From 2000 to 2012, the cumulative profit of industrial firms in Erdos City consistently grew, with a notably rapid development rate. However, between 2013 and 2020, the total profit exhibited a declining tendency. Thus, Erdos' industrial structure underwent initial adjustments in 2012, while simultaneously implementing limitations and management measures for EE and pollution reduction (Ming et al., 2023).

Table 2-1 Benefits of industrial enterprises above large scale

(Data source: Erdos City Statistical Yearbook (2001-2021))

Years	Revenue from Main Operations (Billions of RMB)	Growth rate (%)	Total Profit (billion of RMB)	Growth Rate (%)
2000	94.1997	-	7.6789	-
2001	107.9751	14.62%	8.9125	16.06%
2002	114.9725	6.48%	7.6234	-14.46%
2003	181.8842	58.20%	12.5793	65.01%
2004	320.9884	76.48%	39.5526	214.43%
2005	439.9949	37.08%	73.1000	84.82%
2006	627.5972	42.64%	106.2	45.28%
2007	912.3134	45.37%	164.5	54.90%
2008	1621.7106	77.76%	299.2	81.88%
2009	2067.2800	27.48%	356.4	19.12%
2010	2790.1300	34.97%	685.82	92.43%

2011	3906.8800	40.03%	779.4	13.64%
2012	4273.9837	9.40%	880.82	13.01%
2013	4407.3288	3.12%	775.3	-11.98%
2014	4363.9427	-0.98%	609	-21.45%
2015	4239.0668	-2.86%	464.6	-23.71%
2016	4718.9188	11.32%	634.4629	36.56%
2017	4387.9096	-7.01%	891.1899	40.46%
2018	4234.1284	-3.50%	706.1498	-20.76%
2019	4058.3194	-4.15%	752.444	6.56%
2020	4040.4128	-0.44%	604.24	-19.70%
2021	6675.1493	65.21%	1914.93	216.92%

2.3.1 (b) Erdos Industrial Structure

For the purpose of analysing the influence of EEDs in IP, it is logical for this study aims to evaluate the fluctuations in the proportion of light and heavy industries in the city, as well as their respective growth rates, during the period from 2015 to 2021 according to the chart 2-2. Its goal is to enhance the understanding of this research. According to the Table From 2015 to 2021, the proportion of heavy industry in Erdos City experienced a substantial rise, climbing from 95.3% to 99.26%. Conversely, the percentage of light industry decreased from 4.7% in 2015 to 0.74% in 2021.

This shifting pattern emphasises the potential influence of industrial composition on EE (Li et al., 2023), and demonstrates the unavoidable connection between towns with a strong presence of heavy industry and economic growth, as seen in Erdos' industrial expansion (Andersson & Karpestam, 2013; Ming et al., 2023).

Hence, the alteration in the ratio of heavy industry is subject to impact and interference from both the 13th Five-Year Plan and policies (EHCG, 2022).

Considering the factors that influence EE, PFs can facilitate the implementation of cutting-edge EE of TI, thus fostering sustainable development (Costantini et al., 2013; Töbelmann & Wendler, 2020).

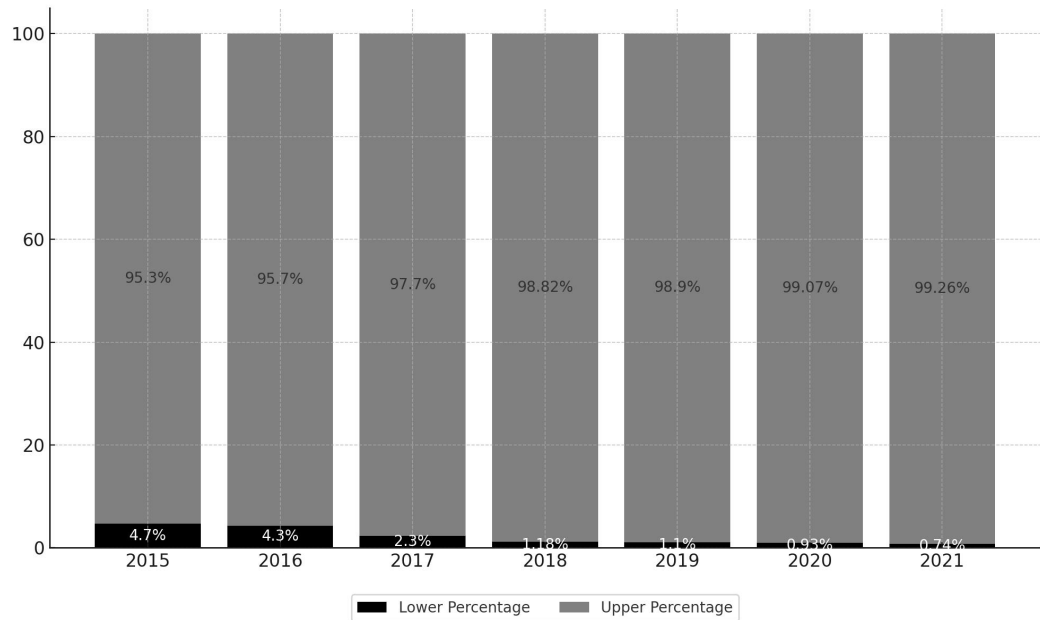


Figure 2-2 The proportion of light and heavy industries in Erdos City
(Source: Erdos City Statistical Yearbook (2013-2022))

2.3.1 (c) Erdos Carbon Intensity

In general, the majority of Erdos City's carbon emissions come from the combustion of coal, oil, and natural gas (Zhang et al., 2021). Indeed, the region has experienced a consistent increase in carbon emissions from industrial energy sources over time (Ming et al., 2023). This phenomenon can be attributed to the simultaneous advancement of carbon intensity and economic development (Andersson & Karpestam, 2013).

Coal emits the most carbon dioxide, comprising over 95% of industrial carbon

emissions in Erdos City between 2012 and 2021. In contrast, oil and natural gas contribute a comparatively lesser amount. The aggregate quantity of industrial carbon emissions in Erdos increases by a factor of 2.32 from 2012 to 2021, from 426.88 million tonnes of standard coal in 2012 to 992.14 million tonnes of standard coal in 2021 (**Table 2-2**). Therefore, industrial carbon emissions in Erdos City mainly depend on coal Carbon Consumption (Zhang et al., 2021).

Table 2-2 Carbon Emissions from Major Energy Sources in Erdos City
(10,000 tons of standard coal)

Years	Coal carbon emissions	Oil carbon emissions	Gas carbon emissions	Total industrial carbon emissions
2012	42387.04	180.03	120.72	42687.78
2013	45900.38	178.90	119.71	46198.99
2014	41181.65	208.75	115.39	41505.79
2015	55600.30	173.63	88.50	55862.43
2016	53317.07	165.66	171.70	53654.43
2017	61757.10	201.86	184.59	62143.55
2018	77432.26	197.63	172.27	77802.17
2019	90953.56	265.04	248.95	91467.55
2020	96388.25	267.52	292.14	96947.91
2021	98559.32	230.28	424.95	99214.56

(Source: Erdos City Statistical Yearbook (2013-2022))

This study applies the ratio of total carbon emissions to regional GDP to measure carbon emission intensity, which is consistent with the academic usual (Baksi & Green,2007 ; Giacone & Mancò, 2012). Overall, the carbon emission intensity in Erdos City exhibited a variable rising trajectory from 2012 to 2015, with