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Research and Experience Reference on China's Implementation of Low Carbon Strategy

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Abstract

Economic development has brought about global greenhouse gas emissions, which in turn has brought about global climate change. This research paper aims to compare the strengths and weaknesses that China has demonstrated in the implementation of its low-carbon city strategy and to summarise the valuable experience that China can provide to the world in the implementation of its low-carbon city strategy. This essay analyses in depth the advantages that China has shown in the areas of renewable energy use and government mechanisms, as well as the shortcomings that it has shown in the areas of eco-efficiency industrial structure and capacity upgrading. Then, the paper summarises the successful experiences of the Chinese government in the establishment of renewable energy use and governmental mechanisms, such as the local government's ability to coordinate multiple sectors (industrial sector, energy sector, etc.) and the implementation of responsibilities. In comparison, the paper also further discusses that China's implementation of a low-carbon strategy in the future may have more eco-efficiency, industrial structure and capacity upgrading.

Keywords

Low Carbon, LCCP, Renewable Energy, Government Mechanism, Eco-Efficiency, Capacity Upgrade

1. Introduction

The establishment of low-carbon towns is now widely acknowledged worldwide as crucial for attaining a low-carbon future. Simultaneously, the establishment of low-carbon cities is both a necessity to combat global climate change and an unavoidable decision for achieving sustainable economic and social progress in China (Yang and Li, 2013). This essay asserts that while evaluating low-carbon cities, it is crucial to consider several indicators, including economic development, social progress, energy structure, living consumption, and environmental quality. Nevertheless, certain scientists only examine urban low-carbon construction by focusing solely on certain variables (Su et al., 2013). This essay contends that the current analysis is not exhaustive. This essay focuses on low-carbon city plans developed in China. By analyzing the strengths and shortcomings of China's low-carbon city policies in concrete execution, the article attempts to assess and summarise the valuable lessons that these strategies may teach other cities across the world, as well as the future problems (Khanna et al., 2014). First, this essay summarizes China's GHG (Greenhouse Gas) emissions and the causes for the LCCP (Low-Carbon City Pilot)'s development. The essay then discusses the benefits and potential drawbacks of implementing the technique. Finally, the essay closes. In addition, this essay highlights the successes of establishing low-carbon solutions that face ongoing hurdles, such as industrial structure and production capacity upgrade. Finally, the essay draws conclusion.

2. Background for Developing Strategy

Globally, countries have made the construction of low-carbon cities a core strategy for addressing climate change. China has formed a multi-level and multi-principal decision-making process for the development of low-carbon cities. China's urban population has risen from 36.2 of the country's total population in 2000 to 54.77 percent in 2014. Statistics show that China's 35 largest cities account for about 18 percent of the country's population and contribute 40 percent of the country's energy use and greenhouse gas emissions (Liu and Qin, 2016). As the world's largest carbon emitter, China accounted for 28.2% of global carbon emissions in 2014 (Song et al., 2020). Total energy consumption increased from 602 million tonnes of standard coal in 1980 to 4.64 billion tonnes in 2018, also making it the world's largest energy consumer.

However, industrialised China faces the dilemma of balancing economic growth and decarbonisation (Dong et al., 2014). Faced with the continuous emission of GHGs, China has implemented various policies to reduce GHG emissions since the late 1990s. The NDRC (National Development and Reform Commission) proposed targets for the first eight pilot cities opened for the implementation of low carbon strategies (Khanna et al., 2014), also called LCCP policy (refer to **Figure 1**). The strategy additionally mandates the pilot regions to compute and establish the overall targets for controlling greenhouse gas emissions in their respective areas. The objective is to construct a regional carbon emission trading regulatory system and registration system by developing a resource allocation programme that is based on GHG emission targets (Huo et al., 2022). Gradually, the development of low-carbon cities has become an important strategy for China in achieving carbon emission reduction. However, due to the different levels of urbanisation, economic development and industrial structure, cities present different development stages and carbon emission scenarios (Shen et al., 2018).

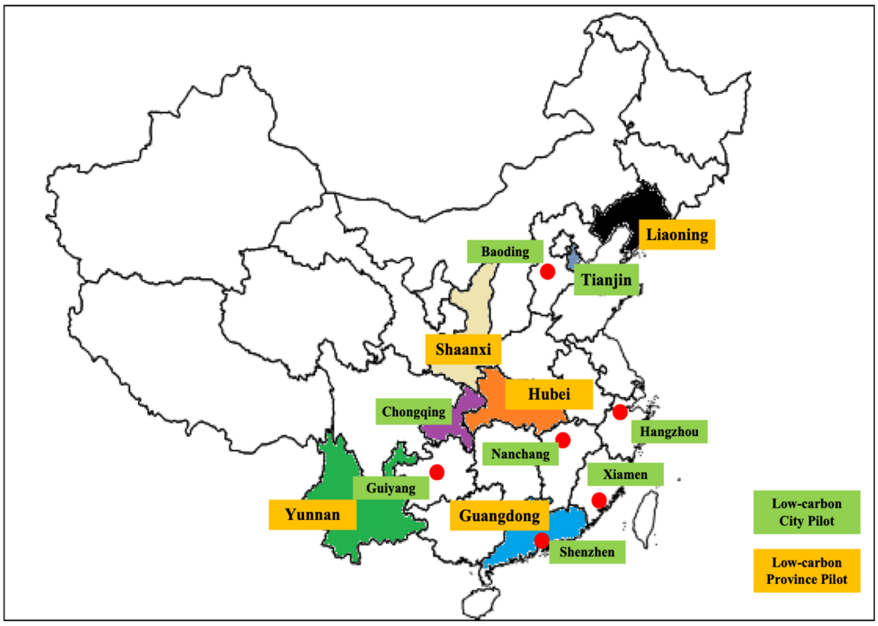

Figure 1. Statistical map of China's national low-carbon provincial and municipal pilot programmes (Dong et al., 2014).

3. Advantages and Potential Disadvantages of Implementing the Strategy

3.1. Advantages in Strategy Implementation

3.1.1. Extensive Use of Renewable Energy

China's remarkable growth in recent years has led to its recognition as the "global powerhouse". Nevertheless, this accomplishment is accompanied by the drawback of being the foremost user of energy and the primary producer of carbon dioxide (Dong et al., 2014). Therefore, the deliberate integration of renewable energy usage plays a crucial role in China's progress towards reducing carbon emissions. At first, recognising that the main cause of CO_2 emissions in the "global factory" is industry, numerous Chinese towns opted to focus on initiatives that improve industrial efficiency, such as the IS (Industrial Symbiosis) system (refer to **Figure 2**). These programmes involve the entire urban region by employing renewable energy sources instead of depending on high-carbon and harmful fossil fuels. The scope includes a wide range of locations, such as schools, marketplaces, houses, offices, and community facilities, where comprehensive methods are implemented to control and decrease carbon emissions (Su et al., 2013). The IS project, executed in Jinan, China, effectively decreases carbon dioxide emissions by approximately 3944.05 tonnes annually (Dong et al., 2014).

Referring to the statistics chart of the pilot projects presented in **Figure 3**, it is evident that Hangzhou has been at the forefront of promoting the development of low-carbon cities in China. Hangzhou has augmented the participation of local governments and the public in the use of renewable energy. This has not only resulted in a more accurate utilisation of renewable energy to fulfil Hangzhou's

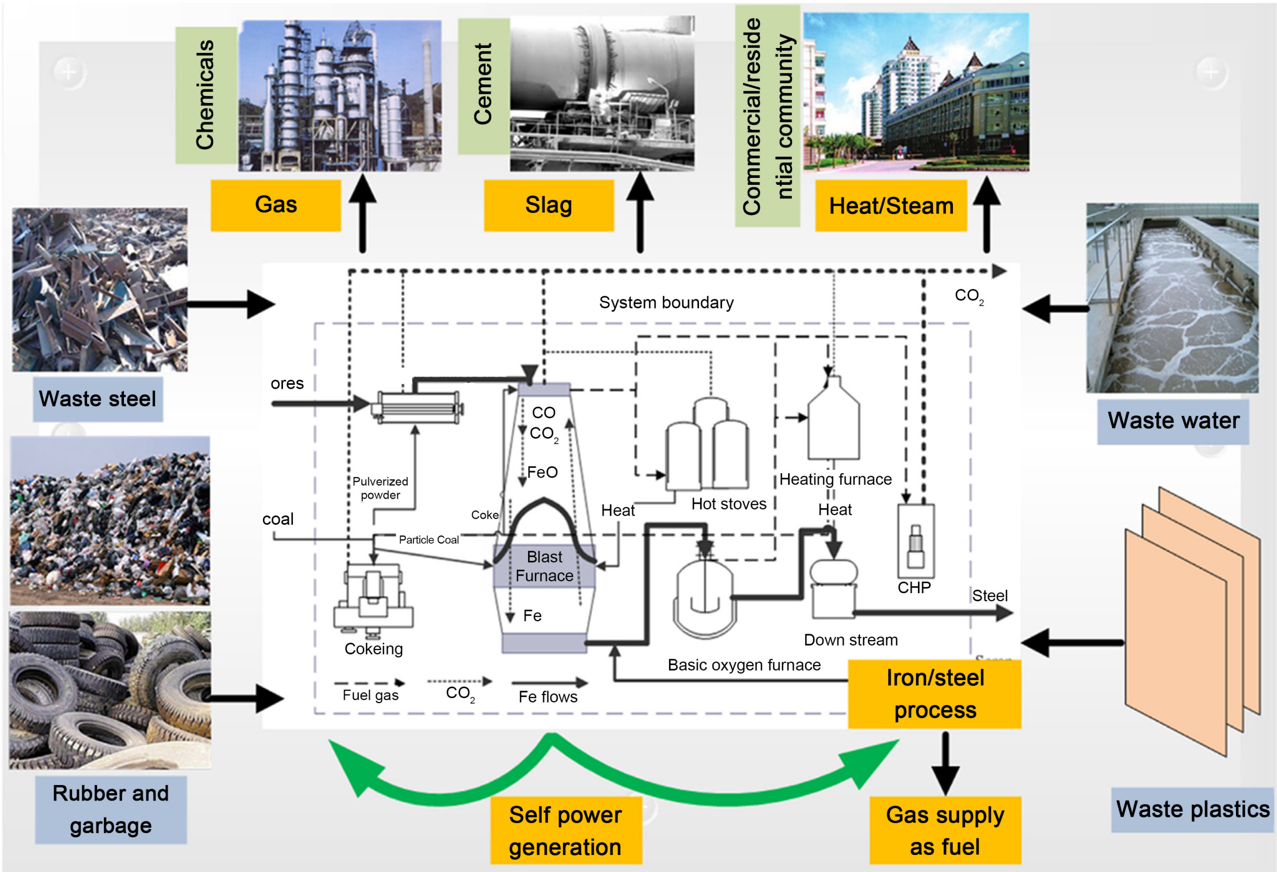

Figure 2. IS system Low-carbon emission solutions for the steel-centred city of Jinan, China (Dong et al., 2014).

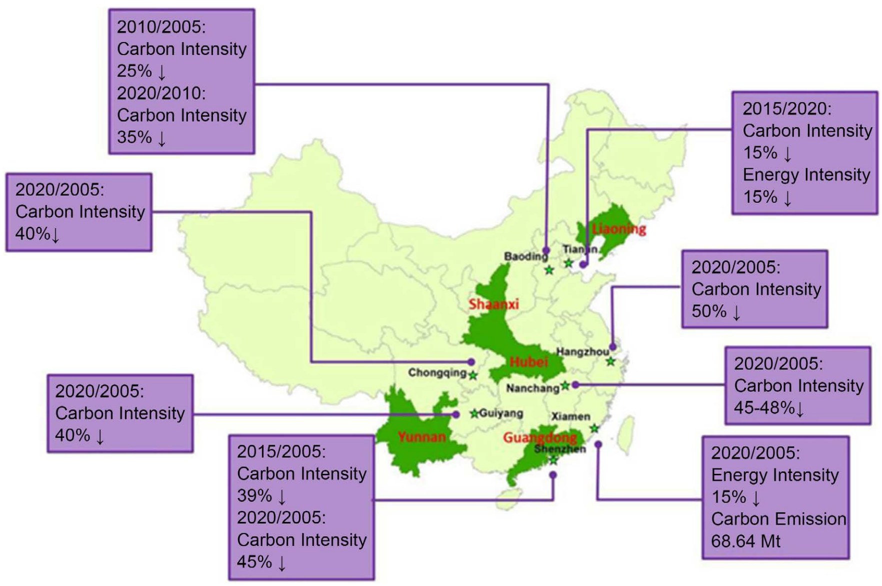

Figure 3. NDRC's targets for the first eight pilot cities opened for low-carbon strategy implementation (Khanna et al., 2014).

ecological requirements, but it has also enhanced public education and knowledge regarding low-carbon principles and actions. As an illustration, the

Hangzhou local government intends to suggest distinct energy utilisation procedures and approaches for various sectors and private enterprises. This will be accomplished by incorporating renewable energy utilisation objectives into specific emission reduction targets tailored to each sector. The local government in Hangzhou has implemented precise control, performance evaluation, and timely modification of strategic goals. This approach has also led to the use of market-based instruments instead of administrative ones. Consequently, Hangzhou has implemented a range of beneficial specialised initiatives to further facilitate the accomplishment of the sector's objectives, relying on evaluation reports created with the involvement of the public (see **Figure 4**). The specific projects and actions outlined in the special programmes can facilitate the successful execution of renewable energy initiatives (Khanna et al., 2014).

3.1.2. Establishment of Efficient Government Mechanisms

An effective government system can offer more opportunities to foster ideas for different policy trials and implementations of low-carbon solutions (Peng and Bai, 2018). Hence, alongside adopting renewable energy approaches, certain cities in China have implemented effective governmental structures to facilitate the execution of low-carbon initiatives, thereby aiding the achievement of strategic objectives and reducing local carbon emissions. Simultaneously, the benefits inherent in the policy mechanisms can be examined from two angles: the execution of responsibilities and the mechanisms that provide incentives. Some cities have a strict low-carbon strategy that requires each local department to implement specific functions and objectives. For instance, in Changchun, China, the focus is mainly on the high-end manufacturing industry sector, with a particular emphasis on energy saving and emission reduction. This includes the closure of local factories that have a significant pollution problem. This mitigates the adverse effects of the industrial sector initially. Meanwhile, Changchun's low energy intensity allowed for the energy sector to collaborate in the execution of the strategy (Lo, 2014). There are numerous such instances of this effective strategic approach to ensure the achievement of China's low carbon policy outlined in the 13th Five-Year Plan (Yang and Li, 2013). For instance, it is quite easy to identify comparable mechanisms employed in fulfilling the demands of the local transport sector. Several municipal departments will assume stringent accountability for decreasing emissions by the 13th Five-Year Plan. For instance, the objective is to decrease car traffic by a minimum of 50 percent during the cycle. Simultaneously, there will be an augmentation in the percentage of individuals utilising walking, cycling, and public transport (Su et al., 2013). In the meantime, the efficacy of the accountability mechanism is further strengthened by modern academic research, such as the DPSIR (Driving Forces Pressures State Impacts Responses) framework (see **Figure 5**). This is because the DPSIR framework suggests that while many cities in the modern world are aware of low-carbon measures, most of these strategies are developed in reaction to external influences and incentives. Urban planning should give priority to tackling the energy, transportation, and construction sectors, as these are the main contributors to greenhouse gas emissions. By prioritising these areas initially, cities can efficiently reduce the overall impact of greenhouse gas emissions (Zhou et al., 2015).

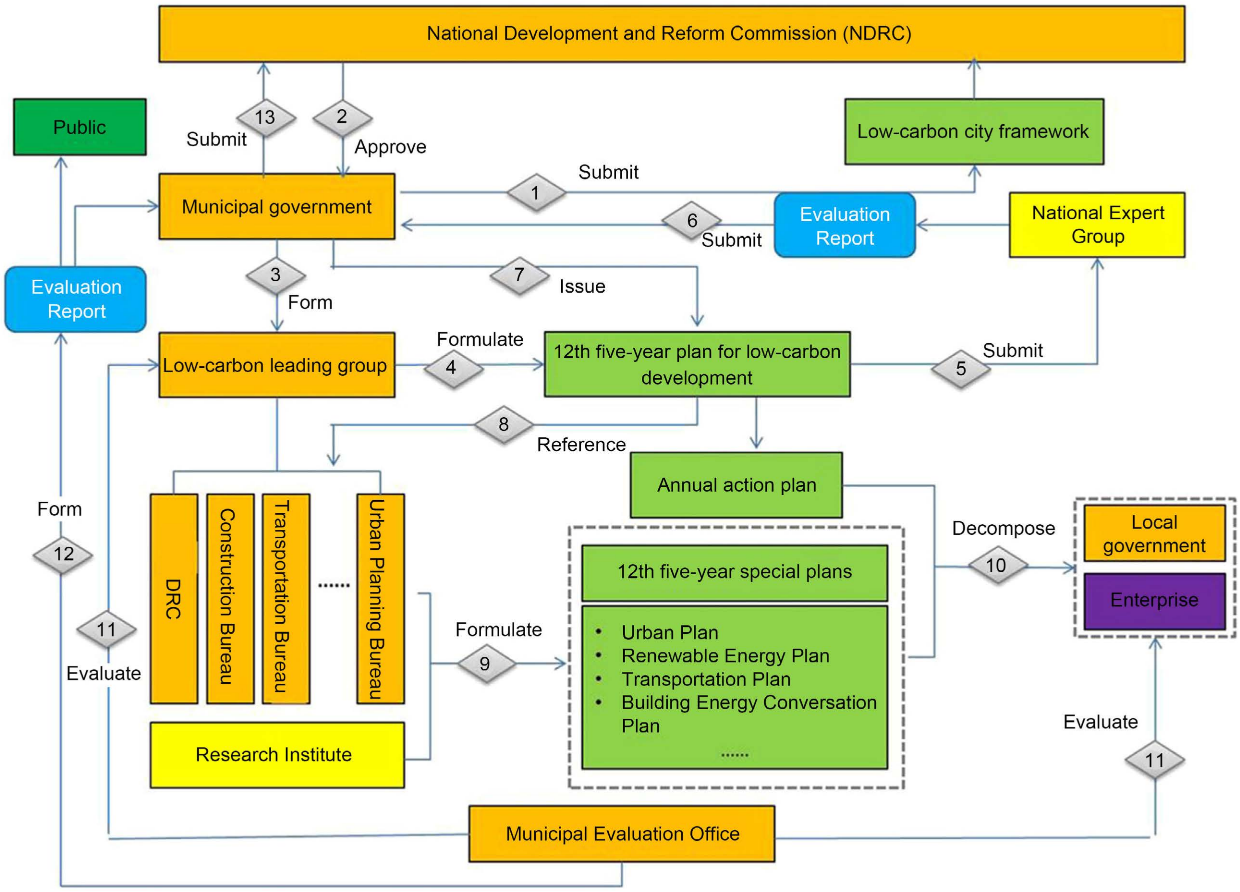

Figure 4. Overall framework for the implementation of a low-carbon strategy in Hangzhou (Khanna et al., 2014).

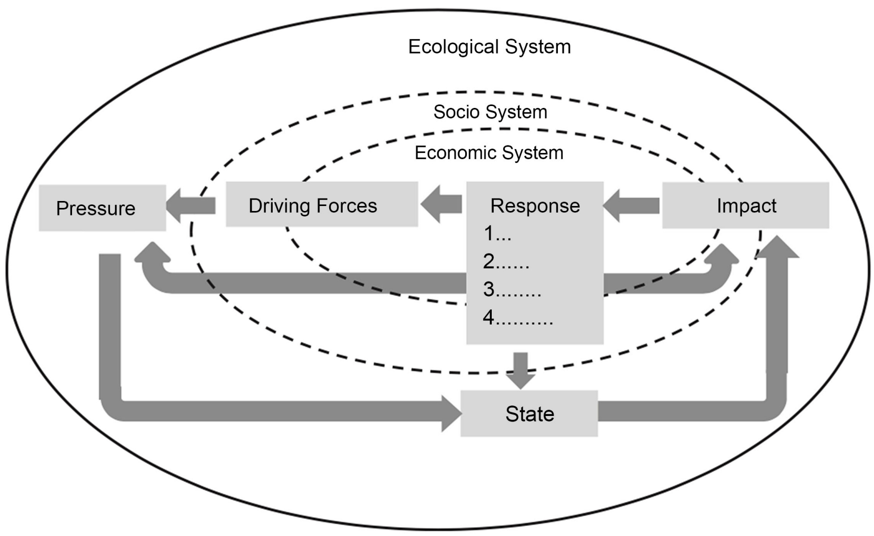

Figure 5. The causal chain of the DPSIR framework and its links to different system scales (Zhou et al., 2015).

However, research indicates that in China's distinct market economy system, establishing strong connections and incentives between the central government and local governments in major cities could create a favourable institutional setting for experimenting with low-carbon policies (Lo, 2014). Shanghai implemented its low-carbon policy by combining incentives with the central government. This approach involved a top-down design, mixed with bottom-up innovation and proactive support mechanisms (see **Figure 6**). The outcomes of this experiment were undeniably effective, leading to the emergence of several innovative policy practices in Shanghai. These include the establishment of local pilot low-carbon developing districts and the implementation of carbon labelling to some extent. Conversely, Shanghai has implemented regular planning cycles at the local level, going beyond top-down aims (Peng and Bai, 2018).

3.2. Possible Deficiencies in Strategy Implementation

The implementation of the LCCP policy in China has accelerated the country's low-carbon strategy, leading to the attainment of overarching goals by embracing renewable energy sources (according to **Figure 7** and **Figure 8**). Furthermore, the effectiveness and method of putting into action have been significantly improved by inventive governmental processes. However, there is still room for further improvement in the implementation of low-carbon strategies. Multiple

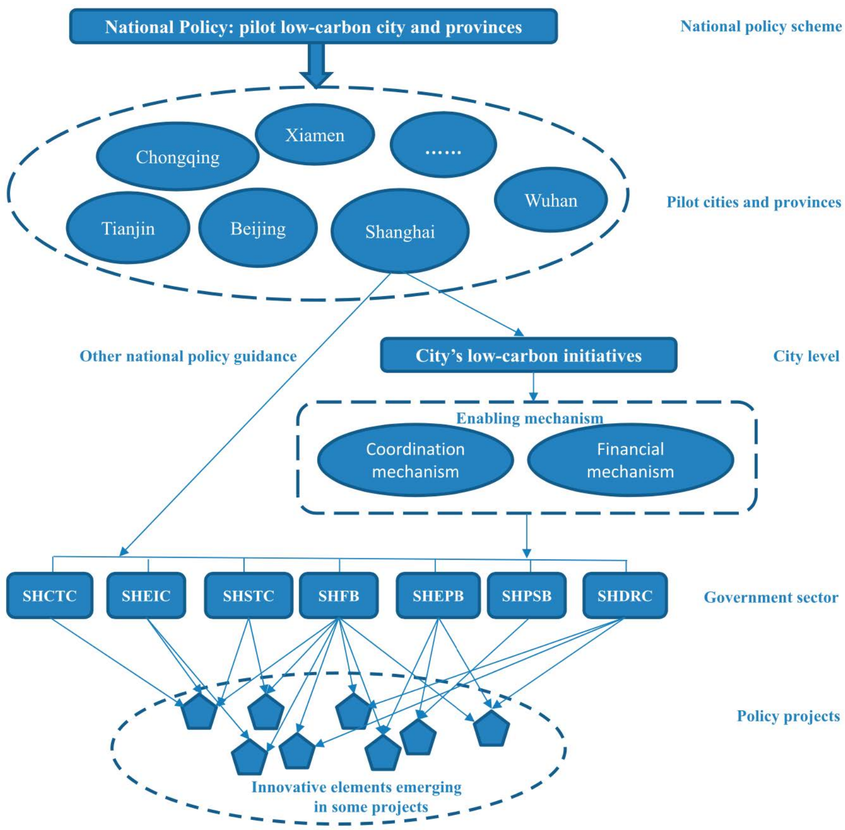

Figure 6. Diagram of the nested structure of the Shanghai model on policy innovation and experimentation (Peng and Bai, 2018).

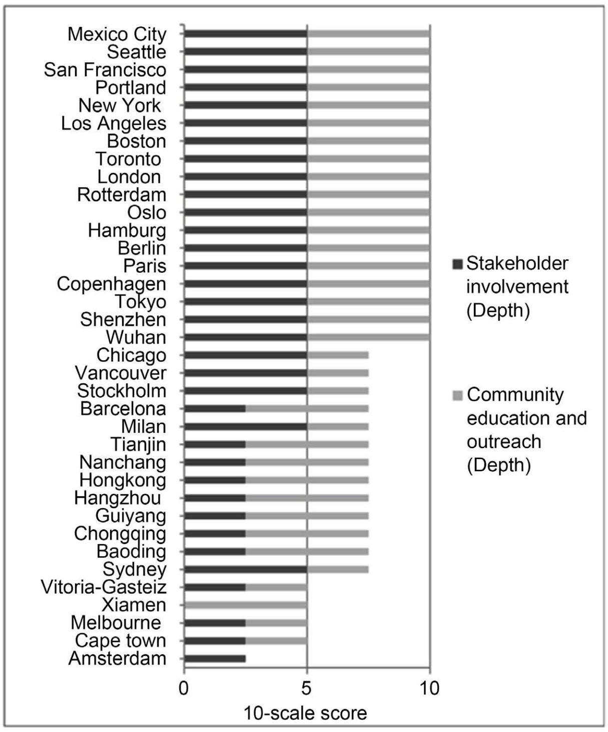

Figure 7. Comparison of scores on cognitive responses in low carbon plans across large cities globally (Zhou et al., 2015).

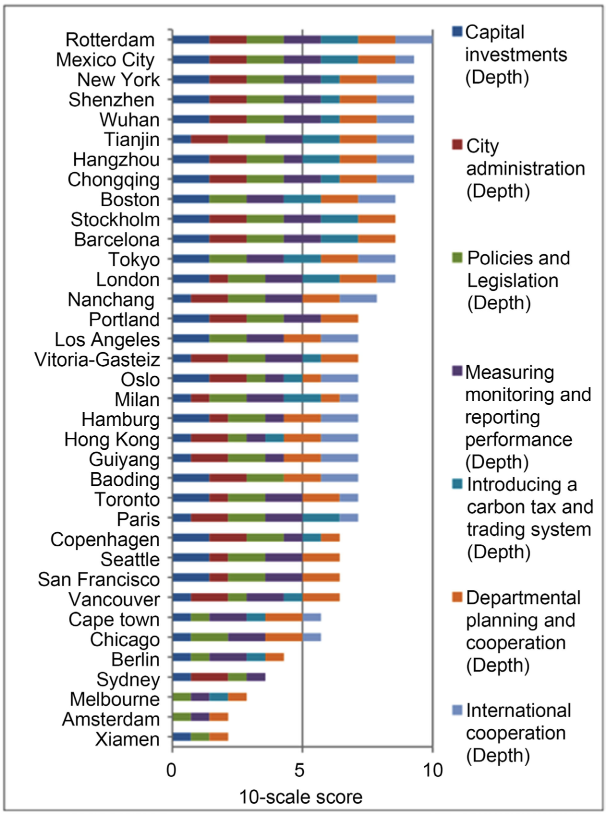

Figure 8. Comparison of scores on institutional responses in low carbon plans across cities globally (Zhou et al., 2015).

studies on urban diversity suggest that specific cities that heavily rely on resources are encountering difficulties associated with their reliance on such resources. This is mostly due to the limited impact of initiatives aimed at creating low-carbon cities and improving eco-efficiency in tackling these issues (Song et al., 2020). The implementation of the strategy has had a limited impact on the city's industries, development of its infrastructure, and energy efficiency, without achieving considerable progress.

3.2.1. Eco-Efficiency

Liuzhou, a typical industrial and resource-based city in China, is facing a resource-dependent conundrum while also working towards implementing the national low-carbon policy. The experiment, known as HPIMO (Hybrid Physical Input and Monetary Output) modelling, was carried out to apply the low-carbon plan (refer to **Figure 9**). The experiment investigated situations including eco-symbiosis in the context of recycling waste plastics, including the recycling of waste tyres and fly ash, as well as the utilisation of biomass. Nevertheless, the study's findings indicate that several of the ecological scenarios outlined earlier actually lead to higher energy consumption and the subsequent release of air pollutants (Dong et al., 2013). This provides compelling evidence that the implementation of low-carbon plans must consider the various additional benefits in the ecological context, such as waste disposal, water utilisation, green infrastructure, and so on. Industrial cities should explore the possibility of converting local waste into fuel as part of their low-carbon strategies. This approach can generate power and heat resources for the eco-city, thereby reducing the environmental pollution associated with low-carbon strategies. Across the globe, in Europe, a novel concept called ULLs (Urban Living Labs) has recently been presented. This phenomenon is evolving into a method of participatory urban governance and experimentation aimed at tackling the sustainability issues and opportunities presented by urbanisation (Voytenko et al., 2016). This will be further elaborated upon in the subsequent section dedicated to analyses.

3.2.2. Industrial Structure and Production Capacity Upgrade

The cities in the LCCP strive to establish a resource-efficient and ecologically sustainable industrial framework (Yang and Li, 2013). They aim to modify the industrial framework and stimulate technological advancement in businesses, consequently enhancing overall factor efficiency and ultimately attaining reductions in emissions (Huo et al., 2022). Yet, the present advantages derived from doing so are quite trivial. This can be largely due to the primary emphasis on the development of energy cycles, namely the adoption of Information Systems (IS) in experimental industrial towns, as the primary catalyst for enhancing low-carbon enterprises. Technologically speaking, the future deployment of IS in cities should be founded upon standardised industrial co-processing technologies and the construction of successful and stable municipal waste recycling systems (Cheng et al., 2019). Despite this, the existing application of IS still lacks a

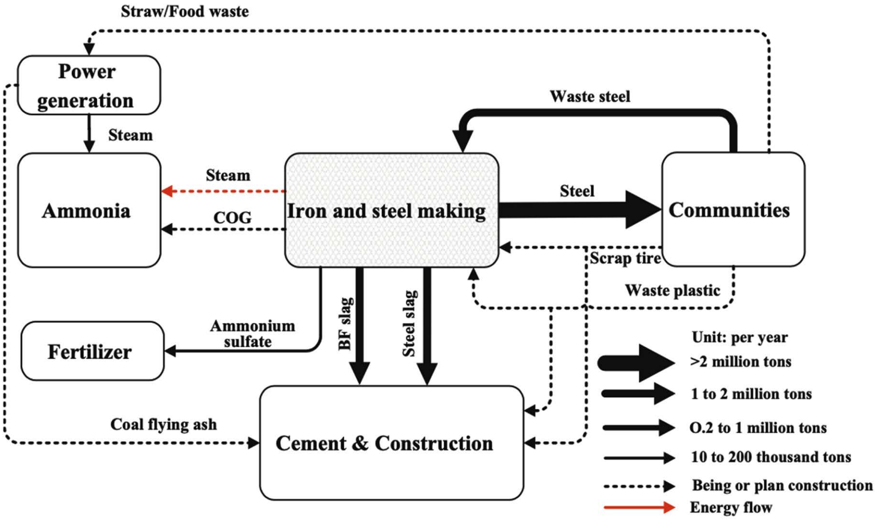

Figure 9. Linkages between existing and potential ecological symbiotic scenarios in Liuzhou City (Solid lines indicate current industrial linkages. Dashed lines indicate potential industrial symbiosis scenarios) (Dong et al., 2013).

thorough comprehension and exact delineation of the term "industry". Additionally, there are considerable difficulties such as the intricate and confusing nature of several simultaneous initiatives in metropolitan locations, as well as the absence of supportive regulations and market-based solutions. These factors may continue to impede the progress of low-carbon development in the future. The lack of a precise definition mostly stems from the varying degrees of urbanisation, economic advancement, and industrial composition of big cities. Hence, cities are in various phases of growth, influenced by implementation, and possess distinct carbon emission foundations (Shen et al., 2018).

Furthermore, the process of upgrading the industrial structure may potentially conceal the possibility of adverse effects on economic progress. China, a rapidly industrialising nation, is confronted with the challenge of reconciling economic growth and decarbonization in the execution of low-carbon initiatives. Industry, being the pioneer in adopting low-carbon techniques, plays a crucial role in the national economy. Indeed, it is also accountable for around 80% of energy consumption and significant CO_2 emissions. Hence, it is important to discover an intelligent approach to synchronise the industrial sector with energy efficiency to accomplish China's objectives in a low-carbon strategy. However, enhancing energy efficiency in various cities necessitates a sensible approach that considers their varying degrees of urbanisation. Central China should eliminate inadequate capacity and actively adopt cleaner, low-carbon capacity as a specific instance. However, the Western region must enable the transformation of traditional high-carbon production capacity, actively promote, and utilise low-carbon technology, and attain an industrial circular economy (Cheng et al., 2019). Therefore, even if most pilot towns have embraced renewable energy, the level of energy efficiency is still insufficient, and the impact of reducing low-carbon emissions is not yet noticeable. At the same time, barriers to increasing capacity quickly worsen the opposition to "capacity elimination" among local governments, as forced closures of facilities have negative social and economic effects. As a result, many local governments have been observed misrepresenting the true capacity of decommissioned plants or repeatedly closing the same facility to obtain additional credits (Lo, 2014).

4. Successful Experiences and Future Challenges in Developing Low-Carbon Strategy

China has recently adopted a low-carbon strategy to tackle the escalating environmental issues caused by fast urban growth. This policy aims to encourage reduced energy consumption, decreased pollution, and the adoption of more environmentally friendly production practices (Qiu et al., 2021). Simultaneously, it strives to attain significant and superior growth in urban areas in China (Phdungsilp, 2010). This essay will now provide a concise overview of the facts and reports, as well as the favourable features of this new urban plan about its achievements in renewable energy utilisation and governmental systems. Additionally, the essay examines the potential adverse consequences of this novel urban approach on both the city and society in the future. This comparison is thought to provide a more distinct understanding of the consequences of low-carbon policies for the world and other highly populated cities.

4.1. Successful Experiences

4.1.1. Extensive Use of Renewable Energy

The Low Carbon Strategy's renewable energy components have been very successful in tackling a variety of sustainability issues. This involves a thorough examination of the IS system that encourages and enables the creation of ecologically friendly surroundings, markets, communities, and families (Su et al., 2013). Across energy-intensive nations around the world, traditional trends of industrialization and urbanization are primarily distinguished by increased levels of carbon emissions and energy consumption in the industrial sector. This not only causes serious ecological and environmental problems such as pollution, ecological decline, and global warming, but it also adds to resource and energy depletion (Cheng et al., 2019). In China, coal and oil consumption accounts for 78% of total CO_2 emissions (Song et al., 2020). As a result, it is undeniably true that China has decided to focus on reducing carbon emissions in the energy industry. Simultaneously, Hangzhou, China, has actively pushed the involvement of local industry in the greater use of renewable energies and has efficiently regulated the allocation of local levies.

China should prioritise the energy transition in the transport sector alongside the industrial sector's energy use in its future low-carbon policy. According to LEAP (Long-range Energy Alternatives Planning) system model in Thailand used by the BMA (Bangkok Metropolitan Area) (refer to **Figure 10**), can provide valuable insights on how to involve local sectors in tackling specific issues. For example, the BMA utilised the LEAP system model to implement its low-carbon

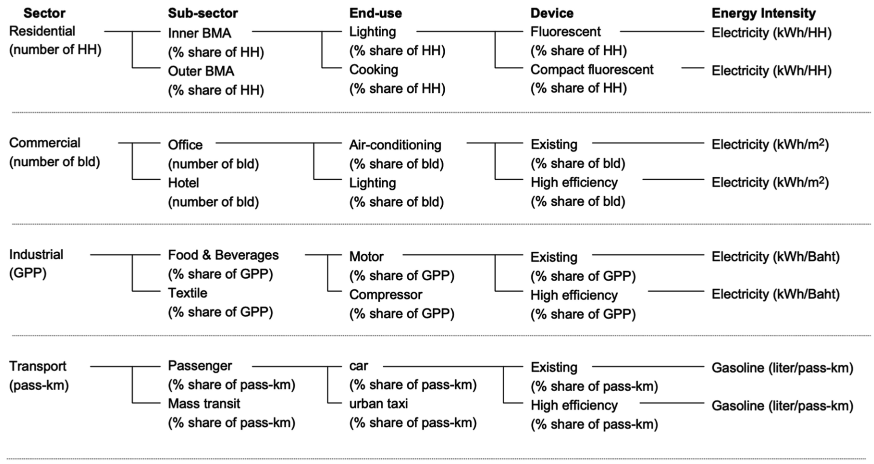

Figure 10. Example of structures of LEAP System model in Bangkok (Phdungsilp, 2010).

policy. Notably, the most substantial energy conservation achieved by this strategy is in the transportation industry. The scenario study demonstrates that by transitioning private commuters to a public transport system, there is considerable potential for reducing energy consumption, CO_2 emissions, and local air pollution levels. Under this circumstance, Thailand can save an impressive 66.14 million tonnes of oil equivalent in energy by the year 2025 (Phdungsilp, 2010).

Simultaneously, the utilisation of renewable energy in China's urbanisation efforts also generates additional ecological and economic advantages for the local region. On the one hand, the utilisation of energy leads to an escalation in the need for pollution emissions from pertinent private businesses, such as industry and the energy sector. In addition, it raises the production expenses for firms that generate pollution, compelling them to relocate from the experimental cities due to reduced profitability. Consequently, numerous sectors that are defined by innovative energy sources are arising, thereby generating more business and employment prospects for the advancement and utilisation of cutting-edge technologies. Additionally, the execution of the strategy motivated the pilot cities to cultivate specific services, such as catering, tourism, and transportation, by utilising low-carbon resources and green technologies (Qiu et al., 2021). The implementation of a low-carbon strategy has been proven to be essential in supporting the development of local low-carbon initiatives and the new economy (Cheng et al., 2019). Meanwhile, the Chinese government has determined that assessing low-carbon initiatives needs both support from environmental rules and outputs from theoretical mechanisms. This is because only by doing so can one comprehend the general low carbon status and pinpoint the related specific limitations (Su et al., 2013).

As a result, the LCCP policy incorporates the utilisation of renewable energy as a comprehensive environmental regulation. This policy also contributes significantly to the advancement of market-based environmental regulations, such as the introduction of GTFP (Green Total Factor Productivity). The primary objective of GTFP is to optimise outputs while utilising the necessary input elements through scientific and theoretical procedures (refer to Figure 11). This guarantees that the use of sustainable energy sources, whenever feasible, aligns with the criteria of an environmentally friendly economy. An analysis of GTFP data from 2003 to 2017 reveals a significant increase in growth rate (refer to Figure 12 and Figure 13). As a result, in the forthcoming utilisation of sustainable energy sources, it is imperative to prioritise the establishment of renewable energy marketplaces across different regions and the development of information platforms for real-time data updates (Song et al., 2020).

4.1.2. Establishment of Efficient Government Mechanisms

The Chinese government has successfully achieved high-quality development by continuously enhancing the efficiency of government procedures in implementing low-carbon initiatives. This experience is valuable and serves as a model for others to learn from (Qiu et al., 2021). The Chinese government has recognised the need to consider various factors, including economic development, social progress, energy structure, living consumption, and environmental quality while

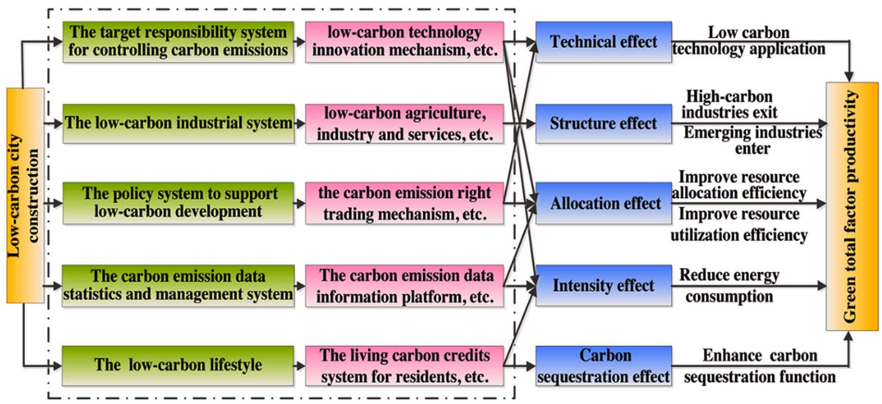

Figure 11. Theoretical mechanisms of the impact of LCCP on GTF (Qiu et al., 2021).

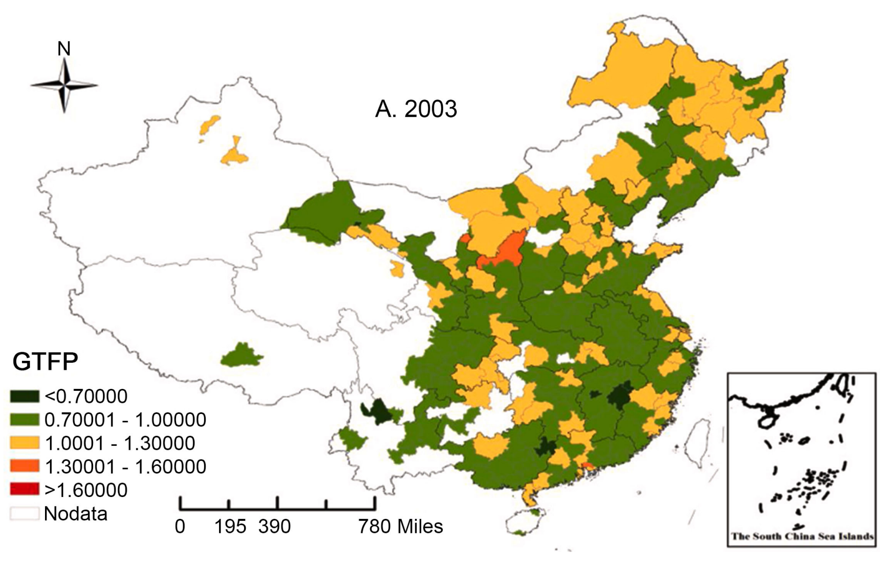

Figure 12. Statistical map of the spatial distribution of GTFP in 2003 (Qiu et al., 2021).

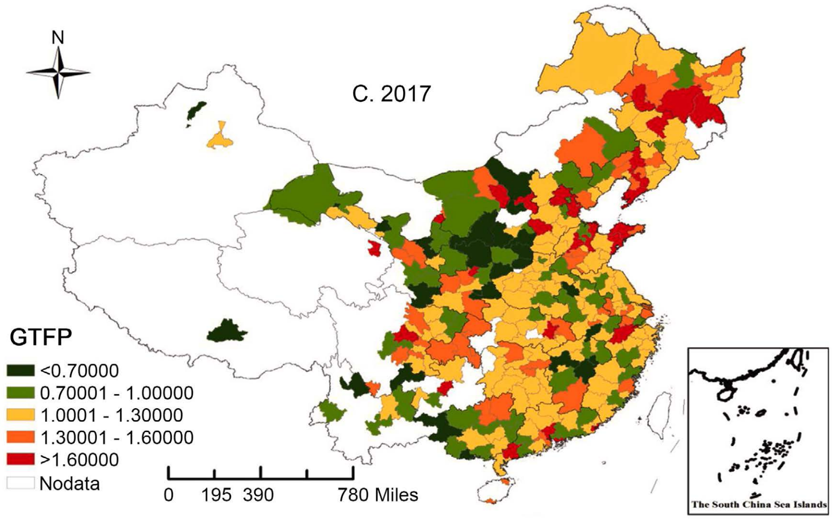

Figure 13. Statistical map of the spatial distribution of GTFP in 2017 (Qiu et al., 2021).

implementing low-carbon initiatives (Su et al., 2013). Thus, throughout the implementation phase, the pilot cities did not solely focus on a single energy or industrial sector function. Instead, they took on duties that encompassed the operations of the local transport sector, leading to a harmonised development across many sectors. Simultaneously, the meticulous execution of the local government's duties in each sector enabled the assessment of the dynamic influence of the comprehensive LCCP policy on GTFP, TC (Technical Change), and EC (Efficiency Change) (refer to **Figure 14**). As expected, there was a simultaneous increase in GTFP and TC as EC expanded from 2014 to 2015. Hence, the government fosters technical progress by developing more effective operational processes. Furthermore, technical advancements in resource allocation, energy intensity, and carbon sequestration have contributed to an increase in GTFP in the pilot cities (Qiu et al., 2021). Moreover, the Chinese government has proactively evaluated the impacts and contributions of various sectors to advance sustainable economic development. Strategically utilising the industrial sector can bring benefits to both the economy and the environment in specific situations. Therefore, academics and policymakers must expand their viewpoint on institutional innovation and make efforts to innovate and develop matching supportive policies (Cheng et al., 2019).

Conversely, certain cities designated as pilot cities, like the Shanghai, have improved their incentives to enhance effectiveness. This has resulted in the development of various innovative policy practices in Shanghai, such as the local pilot low-carbon developing districts, and implementation of carbon labelling. Shanghai also went beyond traditional top-down targets and the adoption of regular planning cycles (Peng and Bai, 2018). The introduction of carbon tagging can also promote a shift in transport mode, moving away from private cars towards public transport systems. This move has the potential to greatly decrease energy consumption, carbon emissions, and local air pollutants (Phdungsilp, 2010). When observing the northern direction, it becomes apparent that the

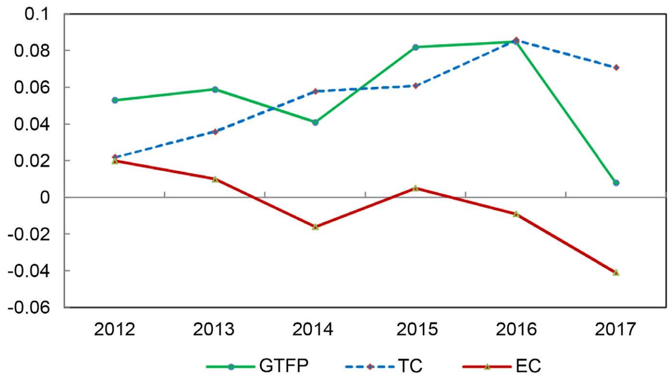

Figure 14. Statistical map of the dynamic impact of the LCCP policy on GTFP, TC (Technological Change) and EC (Efficiency Change) (Qiu et al., 2021).

local government in Beijing is actively promoting the growth of an urban logistics and distribution system by offering incentives. This effort is in response to the additional financial burdens placed on 3PLs (Third-Party Logistics) providers due to the impending carbon tax policy implemented by the central government. Given that incentives establish a robust connection between the central government and the local government in Beijing, the Beijing government can utilise incentives to initially decrease or exempt taxes for select private enterprises.

Furthermore, the local logistics industry in Beijing took use of the incentives to create a comprehensive strategy for developing a low-carbon network plan for the city's logistics and distribution system. This initiative was specifically designed to promote creative techniques that effectively reduce operational logistics costs. Based on this premise, the incentives allowed for model enhancements and a change of the government's carbon tax policy. As a result, urban logistics and distribution systems have made tremendous advances. The CPLEX 12.3 modeling tool provided an accurate depiction of operating expenses. According to the authors, if the operator continues to utilize the same operating costs as before and ignores the possible impact of the new carbon tax on expenses and emissions (as seen in **Figure 15**), overall operating costs will rise drastically and linearly. As a result, the optimised model offers urban logistics and distribution operators the opportunity to significantly reduce their operating costs by up to 9.2% during their services. Furthermore, this approach reduces CO_2 emissions significantly, by up to 54.5% or 2135 metric tonnes (Yang et al., 2016). As a result, China should improve the supply of more attractive institutional frameworks to enable future low-carbon policy experimentation. Simultaneously, it is critical to evaluate the origin and evolution of incentives in the context of local and national policies. Furthermore, the origins and effects of novel policies that aid in the transition to low-carbon urban environments should be thoroughly investigated. Furthermore, it is critical to identify the institutional frameworks and procedures needed to effectively execute policies and promote innovative practices (Peng and Bai, 2018).

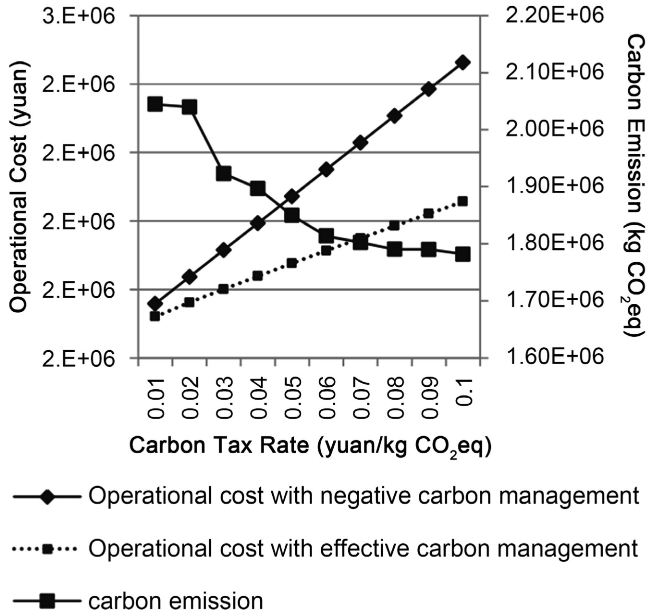

Figure 15. As carbon tax rates rise, both the costs and carbon emissions of urban logistics and distribution systems rise accordingly (Yang et al., 2016).

4.2. Future Challenges

4.2.1. Eco-Efficiency

Effective execution of low-carbon strategies necessitates meticulous evaluation of numerous co-benefits within the natural milieu. It is essential to focus on improving eco-efficiency in industrial cities to effectively implement low-carbon plans in the future. In addition, the current LCCP policies have a negligible effect on eco-efficiency. Upon analysing the control group data presented in **Figure 16**, we are comparing the middle years of 2010 and 2012 in **Figure 16**, while taking into consideration the effects of time, area, and control variables. The findings demonstrated that both categories of low-carbon cities exert a significant impact on the eco-efficiency of industrial cities. The regression coefficients of the two sets of low-carbon city pilot policies are not statistically significant. Therefore, they do not offer enough evidence to support the assertion that the 2010 Chinese low-carbon city pilot policy enhances urban eco-efficiency (Song et al., 2020). Consequently, it is imperative to enhance the integration of the LCCP policy within the natural environment at the city level. Urban eco-efficiency can only be effectively enhanced through careful and precise execution.

The problem is in the technology aspect of applying a more comprehensive approach, which seeks to promote the interdependence of various ecological situations. To address the issue previously mentioned, which involves ecological situations potentially resulting in elevated energy usage and heightened air contamination, the foremost priority that must be addressed is the progression of waste recycling technology. Chinese cities are expected to have a 100% recycling

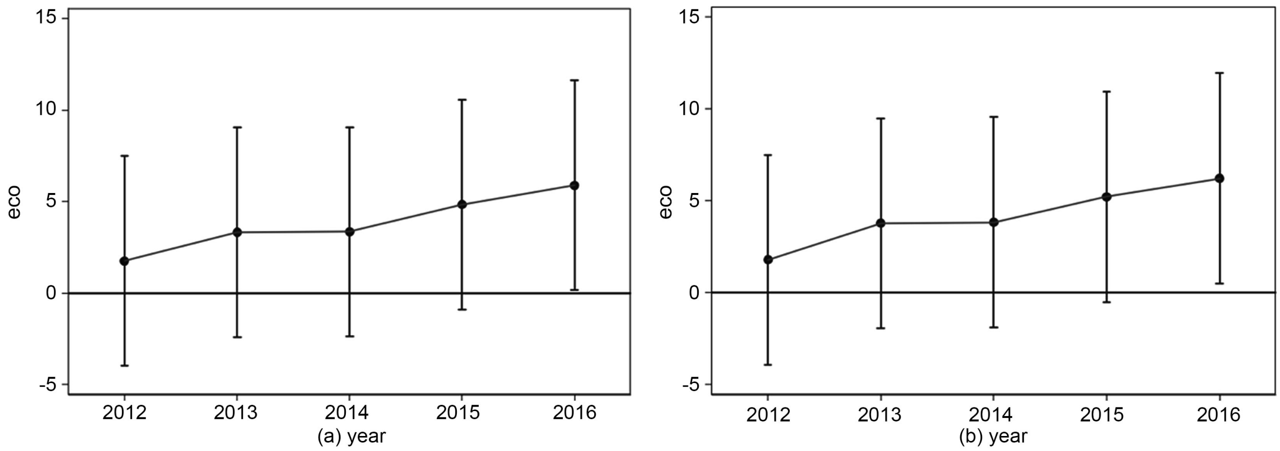

Figure 16. Comparison of the dynamic impact of LCCP policies on eco-efficiency from 2012-2016 (Song et al., 2020).

rate for municipal waste. However, to accomplish this goal, it is important to have state-of-the-art service facilities as a basis, along with the ability to efficiently convert waste into fuel, thereby providing the eco-city with energy and heat resources. To promote efficient resource allocation in the city, this study proposes that the government should enhance the criteria for greening and energy efficiency in urban infrastructure and green buildings (Fu et al., 2021). As an illustration, eco-cities must have a minimum of 40 percent green space in total, with at least 50 percent of it being a publicly accessible, well-maintained, and high-quality network of open green spaces. Furthermore, the attainment of symbiosis in ecological contexts should concurrently foster energy preservation and material reutilization (Dong et al., 2013). Meanwhile, cities may need to establish comprehensive, enduring, and more efficient objectives for water preservation in eco-cities, particularly in regions facing acute water scarcity, such as western China.

An alternative aspect of the difficulty could lead to a significant advancement in the theoretical foundation, such as an ecological study providing additional avenues for enhancing eco-efficient solution strategies. In the present understanding of IS, establishing connections between different industries and between industries and urban communities might enhance the eco-efficiency of urban communities. Nevertheless, the global scholarly community has yet to reach a definitive conclusion regarding whether the industry is "sustaining or causing destruction" (Dong et al., 2014). The progress of the "clean technology incubators" concept, exemplified by Masdar City, has faced similar obstacles, not limited to Chinese cities (Griffiths and Sovacool, 2020). The aim is to encompass a broad spectrum of sustainability factors, such as the sustainability of urban design, transportation, safety, and governance. Additionally, it seeks to improve energy, water, waste management, healthcare, mobility, safety, economic growth, and community engagement (see **Figure 17**). Undoubtedly, urban eco-efficiency relies on technical advancements and economic growth, while ensuring that industrial expansion remains unimpeded. The correlation between knowledge cities

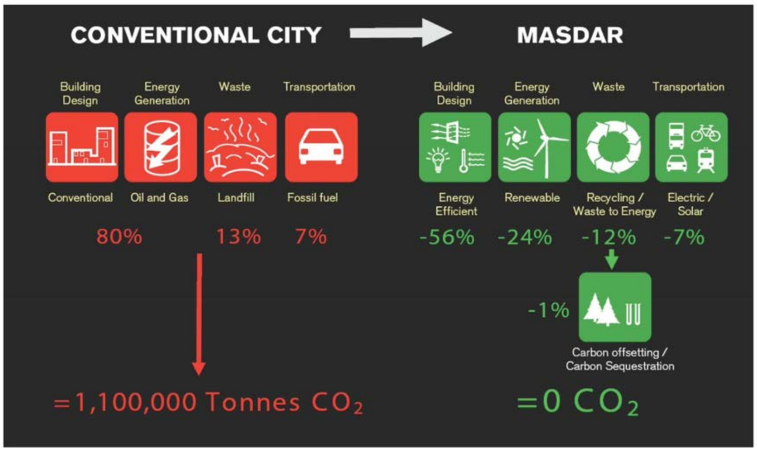

Figure 17. In 2008, the city of Masdar set the ambitious goal of becoming a zero-carbon entity (Griffiths and Sovacool, 2020).

and eco-cities is rational, as it entails the expectation that emerging high-tech service industries can supplant manufacturing as a primary driver of economic development.

Currently, China is pursuing the road of eco-city development (de Jong et al., 2013). However, it is also possible to refer to the prevailing doctrine of ULLs in Europe. This theory posits that the primary factors behind the low-carbon sector are sustainable development and enhanced eco-efficiency. Furthermore, it implies that not all urban low-carbon policies are intended to foster economic growth or increase social cohesion (Voytenko et al., 2016). This research supports the idea that the first objective of implementing a low-carbon strategy should be focused on altering individuals' consumption attitudes and lifestyles. Subsequently, the promotion of low-carbon technology and associated institutions can be employed to effectively mitigate carbon emissions (Yang and Li, 2013). Hence, the optimal approach for implementing low-carbon initiatives revolves around enhancing urban eco-efficiency, minimising natural resource consumption, and mitigating environmental pollution. This would ultimately lead to increased economic productivity and a superior quality of life.

4.2.2. Industrial Structure and Production Capacity Upgrade

Another obstacle to the implementation of China's low-carbon plan may arise from the need to upgrade the country's industrial structure and production capability. Currently, the Chinese government's lack of a precise delineation of industries suitable for optimisation through a low-carbon strategy has resulted in the promotion of low-carbon industries in industrial cities focusing solely on energy recycling, rather than encompassing eco-industries like waste recycling. In contrast, the process of improving the industrial structure may also conceal the potential dangers that could hinder economic progress. Hence, the Chinese government may encounter more formidable obstacles in the future when executing the approach. The low-carbon city pilots are expected to have a more significant effect on optimising the industrial structure in central and western cities compared to eastern cities. This is because the impact of the pilots on reducing excessive industrial development will be more positive in cities with higher levels of urbanisation and stricter enforcement measures (Zheng et al., 2021). The most recent research conducted by Huo et al. (2022) investigates the many ways that pilot cities can employ to mitigate pollution. An effective strategy involves altering the industrial framework to improve overall factor productivity, employing the DID (Differences-in-Differences) model. The study continues by offering a somewhat unconstructive evaluation of the limitations linked to exclusively concentrating on growth in pilot cities (Huo et al., 2022). Facilitating the enhancement of industrial infrastructure in areas beyond the pilot cities is undeniably a hard undertaking. Simultaneously, if strict energy consumption limitations or energy intensity objectives are implemented without a dependable monitoring mechanism, it is probable that local governments may resort to fraudulent activities to control and diminish the scale of their energy sectors (Shen et al., 2018).

Concurrently, the primary factor contributing to the increase in carbon emissions is the expansion of economic output (Shen et al., 2018). The LMDI (Logarithmic Mean Divisia Index) approach was employed to break down the emission factors into components such as energy structure, energy intensity, industrial structure, economic output, and population size. With the rapid development of China's economy, pilot cities are expected to prioritise the preservation of economic production, leading to an increase in technical innovation and the share of the high-carbon industry. Consequently, the issue of excessive industrial structure would worsen significantly, potentially leading to a failure in reducing carbon emissions despite economic development. Local governments in various regions, regardless of their varying degrees of urbanisation, should establish a technical platform to facilitate research and development in industrial restructuring and the advancement of environmentally friendly technology.

In addition, they can promote the growth of high technology-intensive sectors and prioritise the development of environmentally friendly industries to establish an environmentally sustainable industrial framework tailored to local circumstances (Zheng et al., 2021). In the meantime, enhances the frequency of information platform releases in terms of technological advancements, configurations, and impact. On the one hand, in conjunction with IS, China may also need to compile more lists of NIS (National Information System) technologies in the future. The public and private sectors are urged to facilitate the dissemination of industrial exchange information at both the municipal and industrial park levels.

China's low-carbon policy may face challenges not just in terms of industrial structure, but also in capacity upgrading and energy efficiency. This is because the secondary industry today consumes a substantial quantity of energy and emits over 50% of carbon dioxide, which has an almost impossible short-term elimination impact. For instance, in the case of Beijing, **Figure 18** unequivocally demonstrates that during the city's time of rapid expansion from 1995 to 2004,

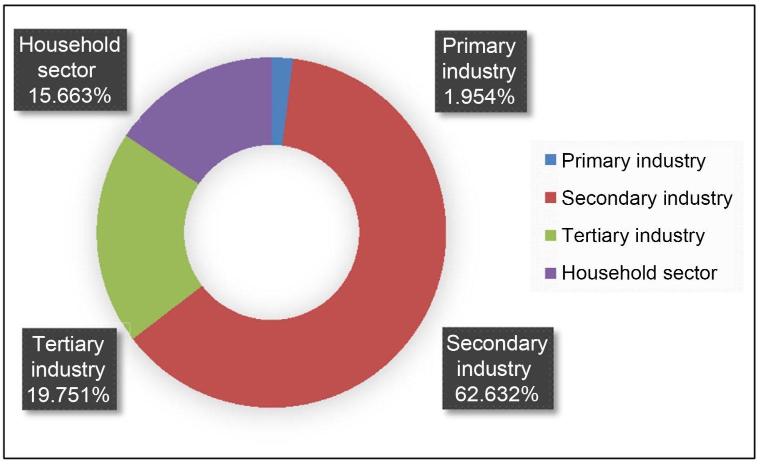

Figure 18. Energy consumption by different industries and household sectors in Beijing during 1995-2004 (Shen et al., 2018).

the secondary industry's energy consumption reached an alarming 62.632%. As a result, the central government may initially need to alter its perspective that the optimisation of the energy system can lead to the city's long-term development, rather than focusing solely on short-term investments and profits (Cheng et al., 2019).

Additionally, the government may encounter the regional hazard of inconsistent capacity enhancement. The DID model is commonly employed in numerous contemporary research to ascertain the influence of GTFP resulting from the adoption of low-carbon measures. Some research findings indicate that capacity upgrading has a notable and favourable influence on GTFP in pilot cities. Furthermore, this impact becomes more pronounced over time. In addition, pilot cities exhibit a greater emission reduction effect compared to non-pilot cities (Qiu et al., 2021). The DID model validates the existence of regional discrepancies in the impact of low-carbon city development on energy consumption. The reason for this is that the growth rate of GTFP (Gross Total Factor Productivity) in the eastern region is considerably higher than that in the western region. Therefore, it is imperative for the government to focus on improving the energy infrastructure in the western region (Cheng et al., 2019). To support cities that depend on natural resources, it is imperative for the government to set realistic targets for decreasing emissions in the industrial and energy sectors, considering both the total amount and the proportionate amount. In addition, it is imperative to undertake initiatives aimed at restructuring deteriorating cities and fostering the growth of new economic catalysts (Qiu et al., 2021). Furthermore, there is a possibility that certain blind capacity upgrades could result in communities providing inaccurate information about the capacity of closed facilities to acquire extra credits. To mitigate the potential for inaccurately reporting capacity, this essay proposes that the central government should initially offer financial aid to underdeveloped areas. This support would enable these regions to comply with carbon emission limits by implementing energy-saving measures and deploying renewable energy sources (Lo, 2014). Moreover, local governments must develop novel technologies aimed at enhancing their ability for urban eco-efficiency improvement. Technological innovation is essential for promoting the development of industrial structures, optimising capacity structure, and enhancing energy efficiency and eco-efficiency in the construction of low-carbon cities (Song et al., 2020).

5. Conclusion

In conclusion, by discussing the strengths and weaknesses of implementing a low-carbon city strategy, this paper identifies the lessons learnt from the successful implementation of a low-carbon strategy in China and the potential challenges ahead. On the one hand, the implementation of low-carbon strategies in China has been undoubtedly successful in terms of both renewable energy and

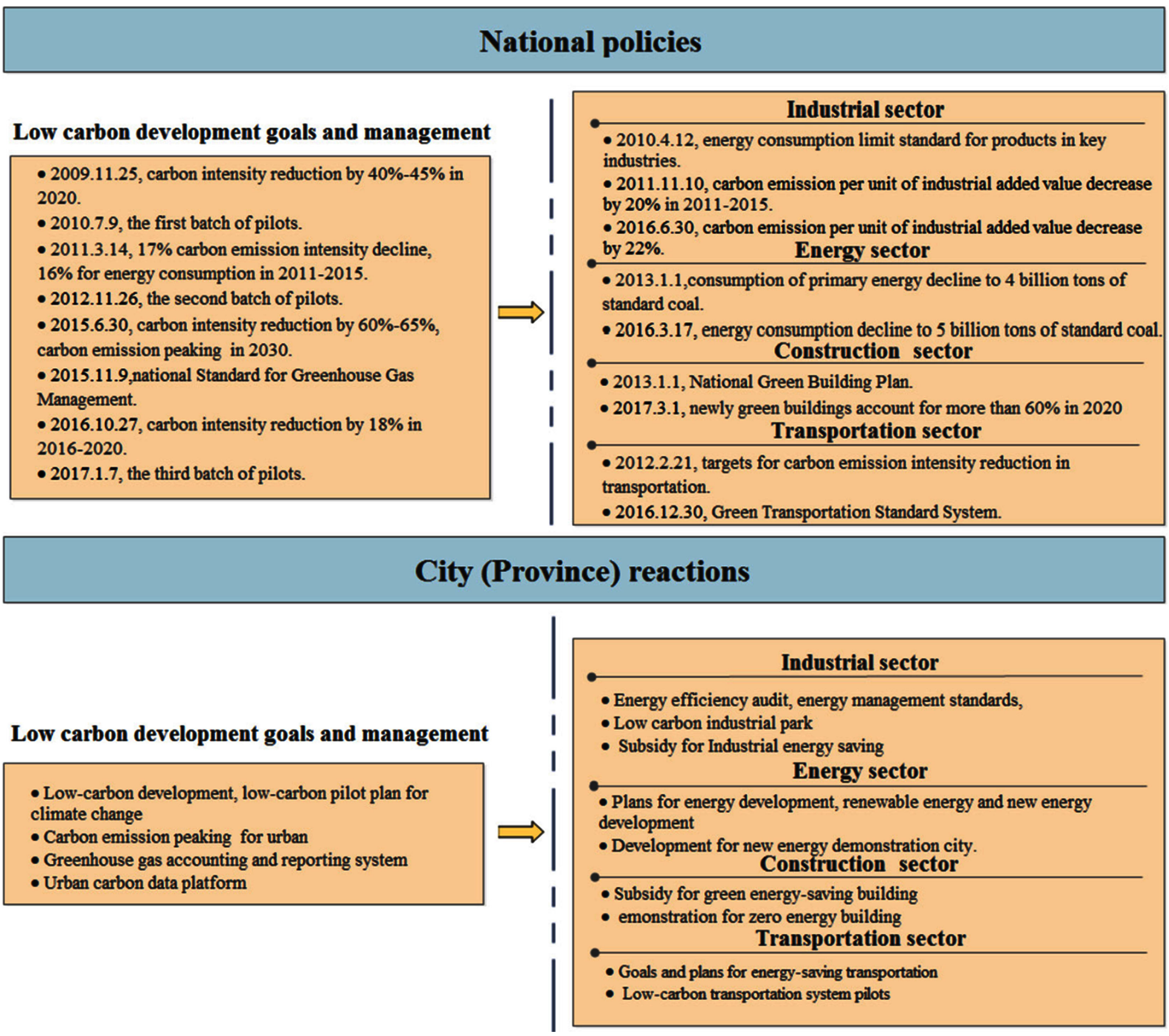

Figure 19. Implementation of national policies and city reactions currently in China (Cheng et al., 2019).

government mechanisms. Renewable energy has not only generated greater efficiency in industry, but local governments have also targeted energy use with precise emission reduction goals for each sector. As a result, China has achieved 100% renewable energy coverage, as demonstrated by the IS system, resulting in increased green economic advantages at the local level. Furthermore, China's governmental processes allow for greater testing and implementation of diverse low-carbon programs. Moreover, the combination of local and central government incentives has facilitated the implementation of the strategy. Local governments in China have demonstrated their ability to co-ordinate multi-sectoral efforts through efficient government mechanisms, including the industrial sector, energy sector, construction sector and transport sector (see **Figure 19**).

On the other hand, some resource-based cities in China have also fallen into resource dependency, mainly due to the insignificant effect of low-carbon city building on improving eco-efficiency. Simultaneously, the execution of the strategy has a diminished effect on urban industries, the enhancement of capacity structure, and the efficiency of energy utilisation. Hence, this paper contends that low-carbon cities, as a novel urban development paradigm, should offer viable solutions to address the conflict between urban growth and the preservation of resources and environmental protection in traditional cities' sustainable development dilemma (Cheng et al., 2019). Meanwhile, China should also do more to encourage pilot cities to carry out comprehensive changes in the future to enhance productivity and adapt the industrial structure (Fu et al., 2021). The government should not only advocate for the adoption of environmentally friendly buildings, but also enhance energy efficiency regulations for urban infrastructure and facilities. Furthermore, it is imperative to actively advance the growth of low-carbon technologies and industries, as well as foster the adoption of green and circular development practices. This will ultimately result in the establishment of more resource-efficient and environmentally friendly industrial structures, production processes, and urban lifestyles (Yang and Li, 2013).

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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