RENEWABLE HEAT POLICY AND ITS IMPLICATIONS ON CLIMATE CHANGE IN CHINA

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RENEWABLE HEAT POLICY AND ITS IMPLICATIONS ON CLIMATE CHANGE IN CHINA

by

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LIST OF ABBREVIATIONS

RES-H	Renewable heat
RES-E	Renewable electricity
IEA	International energy agency
AHP	Analytic Hierarchy Process
CPCA	Consensus PCA
GHG	Greenhouse gas
SAM	Social accounting matrix
CGE	Computable general equilibrium
I-O	Input-output
PII	Policy Intensity Index
BAU	Business as usual
NEA	National energy administration, P.R.C
NDRC	National development revolution committee, P.R.C
MEE	Ministry of Ecology and Environment, P.R.C

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DASAR HABA YANG BOLEH DIPERBAHARUI DAN IMPLIKASINYA TERHADAP PERUBAHAN IKLIM DI CHINA

ABSTRAK

Tesis ini memberi tumpuan kepada implikasi instrumen dasar yang berbeza untuk meningkatkan penembusan pemanasan boleh diperbaharui di China, sejajar dengan matlamat negara untuk memuncak pelepasan karbonnya menjelang 2030 dan mencapai neutral karbon menjelang 2060. Tesis ini menggunakan gabungan metodologi kualitatif dan kuantitatif untuk menganalisis pelbagai instrumen dasar untuk meningkatkan penembusan pemanasan boleh diperbaharui di China dari 2018 hingga 2035. Dengan menggunakan analisis teks, kecekapan sistem dasar haba boleh diperbaharui semasa dinilai, menonjolkan jurang dasar berbanding negara-negara yang mempunyai penembusan haba boleh diperbaharui yang tinggi. Penyelidikan itu mendedahkan bahawa sistem dasar haba boleh diperbaharui China kebanyakannya didorong oleh peraturan, menunjukkan potensi dasar berorientasikan pasaran untuk memainkan peranan yang lebih penting. Model Keseimbangan Umum Boleh Dikira (CGE) dinamik rekursif yang disesuaikan dibangunkan untuk meramalkan kesan instrumen dasar yang berbeza. Hasil simulasi dinamik menunjukkan bahawa subsidi boleh meningkatkan Keluaran Dalam Negara Kasar (KDNK) dan penggunaan tenaga sambil mengurangkan intensiti tenaga, jumlah pelepasan karbon, dan intensiti karbon dengan meningkatkan bahagian tenaga boleh diperbaharui dalam campuran tenaga. Sebaliknya, pelaksanaan cukai karbon membawa kepada pengurangan jumlah penggunaan tenaga, intensiti tenaga, pelepasan karbon, dan intensiti karbon, sekali gus meningkatkan penembusan tenaga boleh diperbaharui dalam campuran tenaga

dan membendung kos utiliti kediaman. Analisis perbandingan mendedahkan bahawa senario dasar hibrid menawarkan kesan yang lebih positif terhadap pembangunan ekonomi, pengurusan alam sekitar, kawalan tenaga, dan faedah sosial berbanding dengan dasar individu.

RENEWABLE HEAT POLICY AND ITS IMPLICATIONS ON CLIMATE CHANGE IN CHINA

ABSTRACT

This thesis focuses on the implications of different policy instruments on increasing the penetration of renewable heating in China, in line with the country's goals to peak its carbon emissions by 2030 and achieve carbon neutrality by 2060.This thesis employs a combination of qualitative and quantitative methodologies to analyse various policy instruments for increasing renewable heating penetration in China from 2018 to 2035. By utilizing text analysis, the efficiency of the current renewable heat policy system is evaluated, highlighting policy gaps compared to countries with high renewable heat penetration. The research reveals that China's renewable heat policy system is predominantly regulation-driven, suggesting the potential for market-oriented policies to play a more significant role. A customized recursive dynamic Computable General Equilibrium (CGE) model is developed to forecast the impacts of different policy instruments. The dynamic simulation results indicate that subsidies can boost Gross domestic product (GDP) and energy consumption while decreasing energy intensity, total carbon emissions, and carbon intensity by increasing the share of renewable energy in the energy mix. Conversely, the implementation of a carbon tax leads to reductions in total energy consumption, energy intensity, carbon emissions, and carbon intensity, thereby enhancing the penetration of renewable energy in the energy mix and curbing residential utility costs. Comparative analysis reveals that a

hybrid policy scenario offers a more positive impact on economic development, environmental management, energy control, and social benefits compared to individual policies.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

1.1.1 Climate change and human's actions

Climate change arises as the biggest crisis to the sustainable development of humankind. The latest report from the Intergovernmental Panel on Climate Change (IPCC) underscores the prominent threat that climate change poses to humanity and the global economy. The research unequivocally indicates that taking urgent steps to drastically reduce GHG emissions will be necessary to keep global warming to 1.5 degrees Celsius, thereby averting the worst effects of climate change (Broom & Gray, 2020).

Beginning with the Rio Earth Summit in 1992, the strategy to address climate change was to pursue a collective, binding agreement that would commit countries to act and impose penalties on those that fail to comply. This culminated in the Kyoto Protocol, signed in 1997, which bound 37 industrialized countries to specific emission reductions. Failure to meet these targets would bring penalties of further reduction requirements and suspension from trading carbon emissions. Kyoto was a textbook solution but an utter failure which soon fell apart. The U.S. failed to ratify the treaty, and Canada, unable to meet its commitments, dropped out in 2011. Despite some success with compliance markets, cross border markets in carbon credits never took off. Countries proved reluctant to use large sums of taxpayers' money to pay for more efficient reductions in foreign countries, and attempts to revive Kyoto at the COP15 summit in Copenhagen in 2009 failed. More fundamentally, the remaining parties to the agreement only accounted for one quarter of global emissions. Thus, while their unambitious emissions reduction target of 4% in the two decades from 1990 was easily surpassed, aggregate global emissions skyrocketed nearly 60% between 1990 and 2013. On the eve of the Paris COP, it was estimated that the world was on track for warming of over 3.5 degrees Celsius by the end of the century, prompting the need for global governance to adopt a radical new approach (UN, 2022).

In Paris in 2015, governments finally summoned the will to begin seriously addressing climate change pledging to:

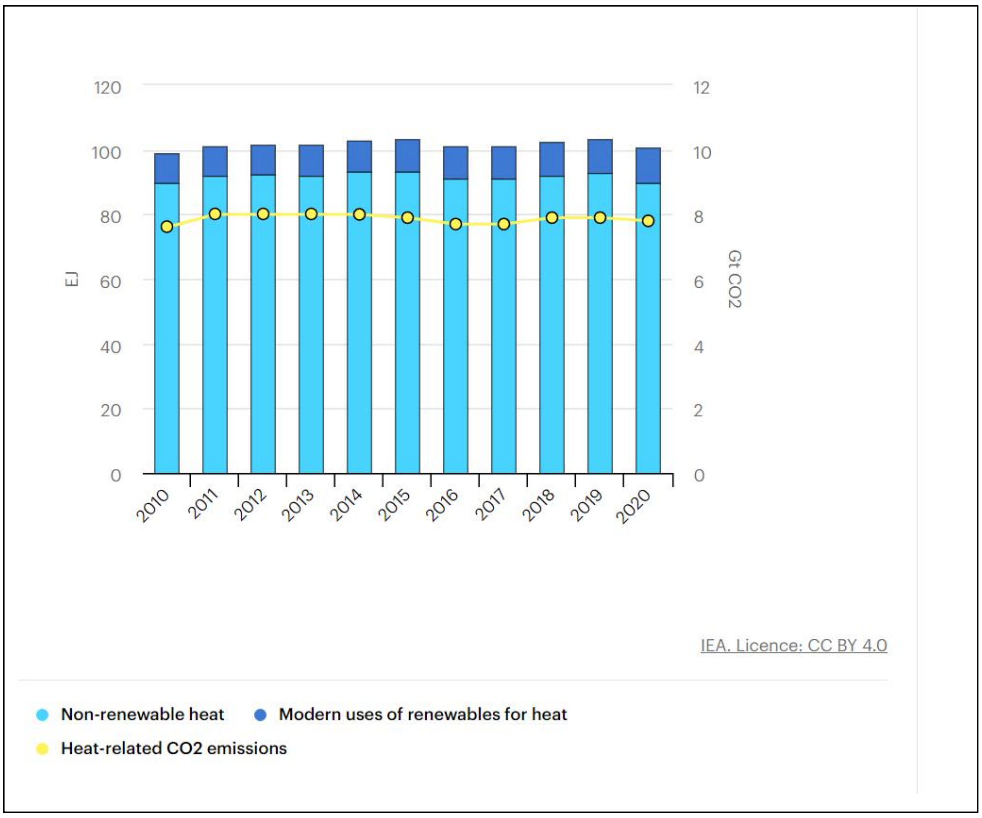
"Maintaining efforts to keep temperature increases to 1.5 ° Celsius over pre-industrial levels and keeping the increase in the world average temperature well below 2 ° Celsius." (IPCC, 2018)

The genius of the Paris Agreement is how it balances this clear global goal with national sovereignty over the policies to achieve it and includes mechanisms to raise ambition over time. To simplify, under the Paris Agreement, countries develop voluntary emissions reduction strategies known as 'nationally determined contributions (NDCs)'. A stock-takes of these plans captures the extent to which the world is converging on its goal. All countries are encouraged to update their efforts regularly through a combination of shared responsibility, peer pressure, and stakeholder activism.

The Paris Agreement encourages governments to be much more ambitious than they had been when facing penalties for failure, and crucially, by retaining sovereignty, it reinforces the legitimacy of the domestic policies necessary to cut emissions and transform economies. The climate agreement had a clear purpose, whose prominence has only increased over time. In other words, the Paris Agreement sets off a global wave of carbon neutrality and net zero carbon. Since then, about 150 countries have made net-zero or carbon neutral goals (Ediboglu, 2018).

1.1.2 The carbon emissions from the heating sector in China

The heating sector is the largest energy-consuming sector and, therefore, a prominent contributor to global CO_2 emissions. In 2021, heat accounted for more over 50% of all final energy use in the world, excessively greater than electricity (20%) or transportation (30%). Of the energy used for heating, 51% is consumed in industrial activities, while 46% is used in buildings for space and water heating, as well as to a lesser extent, cooking (IEA, 2021b). Currently, the majority of heat is still generated from traditional fossil fuels, with renewable energy sources accounting for only 10% of the global heat supply. Moreover, this share has remained essentially constant over the past 10 years. Thus, the heating sector is also one of the most significant GHG emitters (IEA, 2021c).



Source: IEA, 2021

Figure 1.1 Total global energy use and CO_2 emissions for heat: 2010-2020

China is the largest carbon emitter and the second largest economy. More than a quarter of global heat consumption takes place in China, with approximately 70% of which is used in industrial sectors (IRENA, 2020). Fossil energy still dominates China's primary energy consumption. In 2020, the share of coal in China's primary energy accounted for 56.8%, with petroleum's share at around 22% and gas representing 8.4%. Given the large portion fossil energy reliance, China's energy-related CO_2 emissions have significantly increased, from 15% of the global total in 2000 to 31% in 2019 (IEA, 2021a).

1.1.3 China's climate change goals and actions

At the 75th session of the United Nations General Assembly in September 2020, Chinese President Xi Jinping declared that China would aim to peak carbon emissions by 2030 and attain carbon neutrality by 2060 (the "30/60 goals"). These pronouncements will have significant ramifications because practically every part of the nation's energy and manufacturing sectors will need to adjust. Although many of the building blocks for such a significant shift already exist, there are still numerous questions about how to implement it over the course of 40 years. To build the pathway towards a carbon neutral 2060, extensive investigation, careful planning, and coordinated effort will be required over the next few years. Given the size of China and the urgent need to seek a balance between economic development, optimizing energy structure and reducing emissions (Xinhua, 2021) are challenging.

Over the past ten years, China has dominated both production and consumption of energy worldwide. According to World Bank emission estimates, China's energy-related CO_2 emissions are on the rise and accounted for 28% of global emissions in 2019 (World Bank Group, n.d.). Meanwhile, China plays as a major force in the global expansion of renewable energy production capacity, contributing 34-53% of the annual global growth between 2013 and 2021 (Francesco, 2022). Despite a 10% reduction in its proportion in China's energy mix between 2012 and 2019, coal remains the country's principal source of primary energy. China must increase the use of renewable energy sources while decreasing its reliance on coal. Given the significance of these industries to socio-economic development, reducing emissions from hard-to-abate sectors such as cement, petrochemicals, and iron-and-steel production, which are frequently energy and carbon intensive and closely related to heat use, is particularly challenging.

Given the amount of GHG emitted by China, decarbonizing the high-emitting sectors plays a decisive role, not only in achieving China’s carbon reduction goals but also in limiting the global temperature rise and aligning with the goals set in the Paris Agreement. China has implemented a number of policy measures to help slow down global warming, with the following achievements being the most recent:

i. **Updated NDC documents that have been submitted.** After the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change and the 11th Conference of the Parties to the Kyoto Protocol (COP21 conference) in 2015, China prepared and submitted the anticipated INDC agreement in 2016, becoming the 23rd nation to ratify the agreement. China's nationally defined action goals for 2030 were set in 2015. By the end of 2019, it had already achieved its 2020 climate action targets. China updated its NDC in 2020, stating that it would aim to reach carbon neutrality before 2060 and reach carbon dioxide peaking before 2030. It would also reduce its carbon dioxide emissions per unit of GDP by more than 65 percent from 2005 levels and increase the share of non-fossil fuels in primary energy consumption to about 25 percent by 2030 In addition, it would also increase its forest stock by 6 billion m^3 from 2005 levels and increase its installed wind and solar power capacity to more than 1.2 billion kW by 2023(UNFCCC, 2022).

ii. **Carbon peaking and carbon neutrality goals.** China announced its commitment to peak carbon emissions before 2030 and achieve carbon neutrality before 2060. The pledge marks the first time the country has made a long-term commitment to reducing emissions. It is estimated that global warming projections for 2100 could be lowered by approximately 0.2-0.3° Celsius if China achieves its carbon neutrality goal before 2060.

1.1.4 The role of renewable heat

Despite great efforts being made, achieving both the medium and long-term carbon reduction goals is not easy for China, given its current level of CO_2 emissions and economic volume. China will need to maximize the deployment and usage of renewable energy if it is to achieve its carbon peaking and carbon neutrality goals. Direct and indirect decarbonization of end-use sectors, such as buildings, industry, and transportation, must be paired with this, and sustainable use of bio-energy, hydrogen, and synthetic fuels must be stepped up. Conventional thoughts on energy supply and security will be fundamentally reshaped. Meanwhile, the energy transition should be accelerated at pace and scale.

Compared to electricity, renewable energy sourced heat is still a field with huge potential to be tapped on. In China, the reliance on fossil energy is even higher than the global average level (see Figure 1.1), with more than 90% of heat supply came from coal in 2018 and renewable energy contributing to less than 8% of heat supply (Yang, 2019). According to IEA, it's predicted that the global energy consumption will increase to 17 EJ during 2021-2026 at a growth rate of 9%, and this expansion will be mostly driven by the industrial sector, with China accounting for half of it[2]. This means, on one hand, China needs to progressively reduce GHG emissions in all sectors, especially energy-intensive sectors in order to achieve climate change goals. On the other hand, the demand for heat is projected to face growth in the short and medium term[7]. To address the contradictory conditions, scaling up renewable energy deployment in heat supply is crucial.

Among the various of solutions to address climate change, renewable energy is always the centrepiece which needs to be deployed at an unprecedented scale. With remarkable progress in scaling-up renewable power generation, decarbonization in the heating sector, especially renewable energy sourced heat, is worthy of intensive attention to reduce its dependency on fossil fuels, considering its considerable energy consumption and CO_2 emissions.

Renewable energy in China refers to non-fossil energy sources such as wind, solar, hydro, biomass , geothermal, and ocean energy, excluding direct combustion of straw and firewood on low-efficiency stoves (IEA, 2021b).

According to the China Renewable Law and the definition provided by the IEA, renewable energy sourced heat in this thesis primarily comprises the following:

i. Modern bio-energy includes a variety of possibilities, such as solid biomass boilers, co-generation systems that use solid biomass or biogas and are connected to district heating, the injection of bio-methane into natural gas grids, and the use of biogas for direct cooking.

ii. Solar thermal energy is used for some industrial purposes as well as large-scale applications to supply district heating systems, water heating, and some space heating in buildings.

iii. Geothermal energy is utilized in industries, buildings, greenhouses, swimming pools, and district heating systems.

iv. Renewable electricity, generated from renewable sources and used for heating) is used to power heat pumps. These heat pumps also utilize solar heat that has been trapped in the ground or the atmosphere. Renewable electricity may be used in district heating applications and in conjunction with solar photovoltaic (PV) in residential, commercial, industrial, and other settings.

1.2 Problem Statement

The potential of renewable heating has not been fully tapped and renewable heat policy interventions still remain scarce. The reasons for this lag are complex which include but not limited to the following factors as described below.

First of all, competing against established (mostly fossil) fuels, renewable energy-based heating faces a number of challenges. The heating industry is more complicated, fragmented, and generally under-researched than the electrical industry. Effective policy-making is difficult because of its complexity. Building thermal energy demand varies significantly depending on factors namely the environment, the effectiveness of the building envelope, occupancy, behaviour, and many other variables.

Secondly, different industrial processes have different heating requirements. The industrial need for heat varies as different industrial processes may require heat at different temperatures and quantities. On the supply side, a wide range of space and water heating alternatives are available, with numerous actors involved, ranging from large international heating equipment manufacturers to small local installers. The type of fuel used and the size of the heat source also vary, ranging from massive combined heat and power plants to modest open fires. The match of demand and supply can sometimes be very challenging.

Thirdly, there are certain general barriers similar to those for renewable electricity at this early stage, such as high upfront costs, low fossil fuel prices, and subsidies for fossil fuels. Some barriers are more specific, such as applicability, where there might not be enough room for a biomass boiler or industrial temperature standards that make it more difficult to use renewable heating options. The use of heating is generally more location and setting-specific in most occasions[7].

In summary, developing heating policies are very complex and still relatively rare compared to electricity policies. Built upon the experience drawn from renewable energy electricity, policy interventions need to be designed more carefullyand properly crafted to take into account unique national and local conditions (Fan et al., 2021).

Most countries, including China, have long ignored renewable heat compared to the attention paid to the renewable electricity, despite the huge contribution of heat to carbon emissions. For example, while around 150 countries have targets for renewable electricity (Timmerberg et al., 2019), only 47 out of 197 countries had renewable heat targets by 2019 (IRENA, 2023). Although incentives do exist, renewable heating technologies are often only regarded as part of energy efficiency programmes. Frequently, financial supports and concessional loans are provided to heating technology investors with the primary objective of improving energy efficiency, resulting in limited attention to renewable heat (Khan & Majeed, 2023).

Renewable energy is central in decarbonizing the whole energy system. Dedicated policies and measures are urgently needed to act as a key driver for advancing the long-ever neglected aspect of the energy transition. **The experience drawn from renewable electricity indicates that efficient policy interventions can overcome the barriers in the early stage of scaling up renewable energy applications** (Cifuentes-Faura, 2022)**.**

In the context, renewable sourced heat (has been recently highlighted in China, with the introduction of the high-level policy guidance, *Notice on Implementing Renewable Heat Supply According to Local Conditions* (NEA, 2021). The policy document was issued not long after China's carbon neutrality pledge, implying strong support from the top-level policymakers for scaling up renewable energy sourced heat**. While it is clear in relevant Chinese policy documents that policy instruments are to be strengthened, what policy instruments are to be utilized and how they are to be applied are still under discussion due to the differences in the impact generated by various types of policy instruments. Governmental intervention is required to remove obstacles and it must be properly crafted to consider China's unique settings.**

In response, research presented here aims at contributing to the discussion on the merits of various policy instruments related to renewable heat. An additional aim is to innovate combined methodologies and create a prediction of the implication of different policies which can inform future policy-making.

To meet the aforementioned goal, existing policy instruments on renewable heat operating in China from 2010 to 2021 are analysed to identify the structure and characteristics of existing policies to find where the gaps lie. Based on the qualitative evaluation, a simulation using the CGE model is developed to offer a deeper understanding of the impacts of different instruments, especially on climate change goals during the time-frame from 2018 to 2035.

1.3 Research Questions

Given the significance of policies in scaling up renewable energy, several questions were raised:

i. What is the current state of China's renewable heat policies? Are the existing renewable policies in China effective in addressing climate change issues? If not, what are the key barriers?

ii. What is the impact of predicted renewable heat policies on climate change?

iii. What kind of policy scenarios are most effective? And how should we construct the future renewable heat policy framework?

1.4 Study Objectives

The overarching objective of this study is to develop a comprehensive approach for evaluating renewable energy heating policies in China, covering both existing policies and predictions of future policies. The aim is to explore an evaluation methodology to inform the decision-making process in scaling up renewable heat in China with quantitative data. To be specific, the research will revolve around the following objectives:

i. To systematically evaluate China's existing renewable heat policies and to identify the structure, evolution, and key gaps.

ii. To predict the implication of different policy instruments on China's climate change goals and to inform future policy-making.

iii. To provide an innovative and holistic technique for renewable heat policy-making in China.

1.5 Theoretical Framework

The first objective is to empirically examine the evaluation of the renewable heat policies in China. In line with Tu et al. (2020) and Kim (2021), they examined the evaluation of renewable energy policies in China and Korea based on a systematic review of renewable energy policies in chronological order, and analysed the key drivers underlying the policy-making in different stages. This empirical analysis is also utilized in this thesis to sort out the existing policies on renewable heating in China and to find out the key attributes for renewable heat policy-making in China.

Empirical analysis is an evidencebased approach to the study andinterpr etation of information (Carley, 2009). In this study, existing data about renewable heat policies in China are gathered and analyzed to draw conclusions for future policy-making.

For the second objective, the conceptual framework to understand the impact of renewable heat policies on achieving climate change goals is constructed based on the CGE theory which can simulate the interlinks of multiple sectors of the macro-economy. A model which links various sectors with heating policy shocks in the economy, based on a complex series of transactions, is used to understand the impact of renewable heating policies on climate change goals (Burfisher, 2016).

The final objective is to innovate a hybrid methodology to inform future renewable heat policy-making in China based on the empirical analysis of existing policies and predictions of potential impacts of proposed policies. The hybrid methodology applies the Analytic Hierarchy Process (AHP), a decision-making

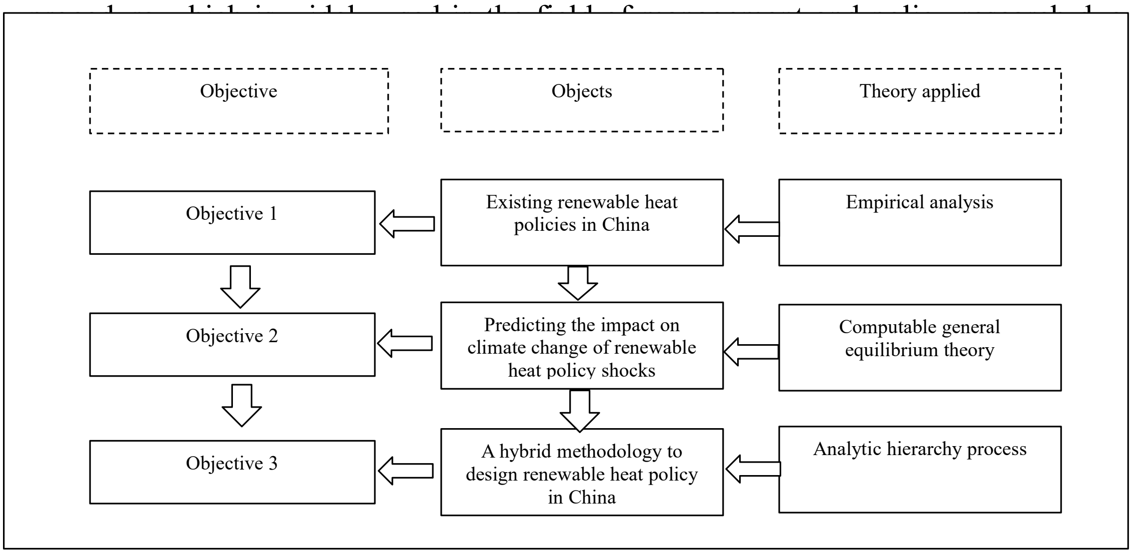


Figure 1.2 The theoretical framework of the study

1.6 Variables of the Study

The independent variable of the study includes the penetration rate of renewable heat in China while the dependent variable consists of the renewable heat policies, including various policy instruments. The study assumes that the renewable heat policies are one of the key factors that impact the uptake of renewable energy in China. This assumption is made based on the experience of renewable electricity in China in which supporting policies played a critical role in stimulating the growth in the initial stage. The relationships between different types of variables can be observed in the figure below.

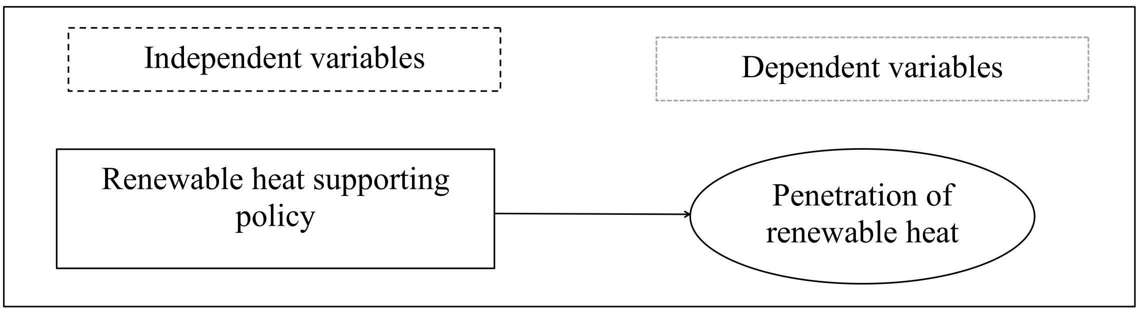
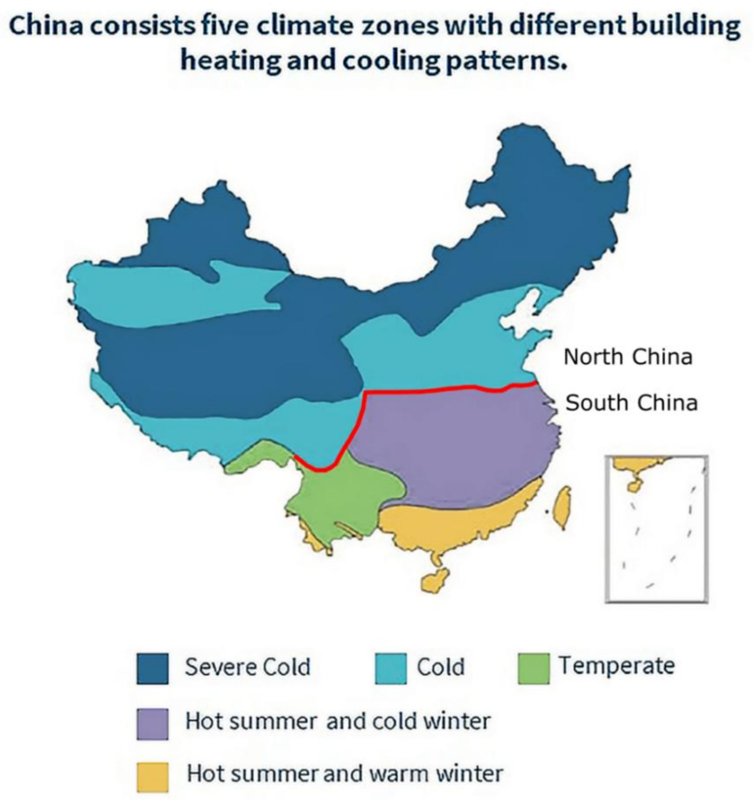


Figure 1.3 The variables of the study

1.7 Research Scope

The research focuses on **mainland China** as the targeted research scope. In China, while two-thirds of the heat demand is from industrial sectors, space and water heating demand are also growing rapidly. The features of heating in residential sectors and industrial sectors are different.

For residential sectors, climate factors should be taken into consideration. China is typically classified into five temperate zones, each with unique heating requirements. The two coldest temperate zones in China are located in Northern China, where space heating is a wintertime necessity. While rural areas primarily employ individual household heating systems, metropolitan areas primarily rely on district heating systems. Additionally, areas with hot summers and cold winters experience increased heating needs. However, buildings in these areas often lack appropriate heating services as no public infrastructure has been established to supply district heating systems due to several historical factors. As a result, China's northern and southern areas face diverse heating-related problems which require specialized solutions.



Source: RMI, report: decarbonization of China's heating sectors

Figure 1.4 China's five climate zones and residential demand

For industrial sectors, heating needs are not directly related to China's climate conditions but are associated with industry distribution. Industrial heating refers to the thermal energy used in industrial process, such as steel and cement production, commonly in the type of steam or hot water. From 2014 to 2021, the market volume of China's industrial heating increased significantly, from 7.36 GJ to 14.13 GJ. China's industrial heat consumption is mainly concentrated in northern areas and enterprise cluster areas such as chemical zones, textile zones, high-tech development zones, economic development zones, and industrial parks. Data shows that East China, North China, Northwest China, and Central China top the industrial heat consumption list, accounting for 36.19%, 19.64%, 12.24%, and 10.76% respectively (China Economy Information research institute, 2022).

Source: google map

Figure 1.5 China's industrial regions

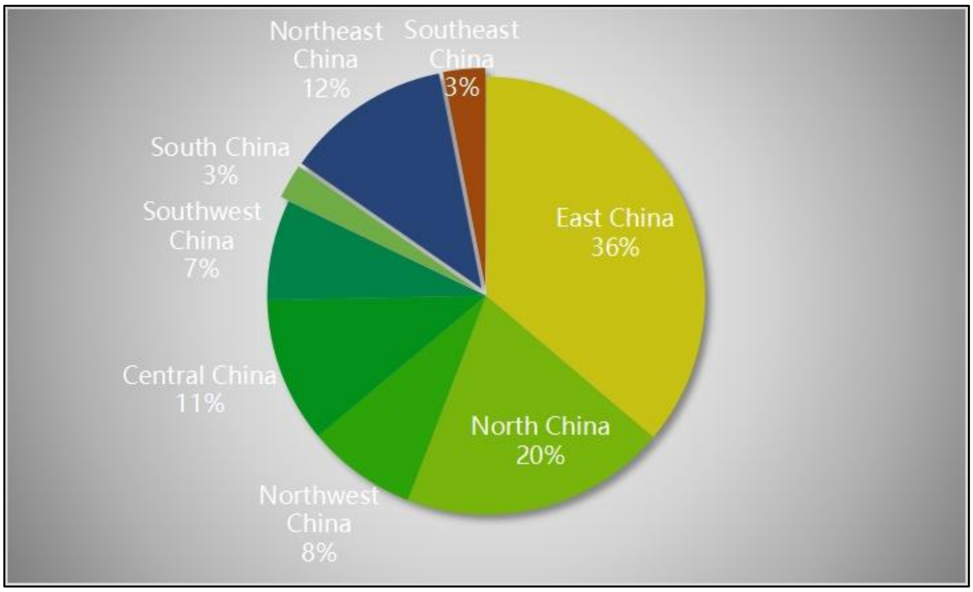


Figure 1.6 China's industrial heat distribution

The research scope of this thesis includes heating policies for both residential and industrial sectors, covering both central level and local level policies regarding renewable energy sourced heat in China.

1.8 Significance of the Research

The significance of this study is manifold.Firstly, our study contributes to deepening the understanding on China's renewable heat policy framework. Although energy use for heating accounts for more than half of global final energy consumption, the heating sector has long been overlooked, with studies in this regard are mostly at an aggregated level with limited details. Renewable energy sourced heat policies are under-researched domestically and globally. Through a systematic review, China's renewable energy sourced heat policy landscape was mapped and the architecture of China's renewable heat policy framework from the perspective of authority and power was analysed. Building on that, the effectiveness of existing policies and gaps was analysed using qualitative methods. The findings of the study can improve the understanding of China's renewable energy sourced heat status, challenges, and benefits of the future policy-making.

Secondly, this study focuses on renewable heat policies, which to date have been understudied in energy system modelling literature. This thesis constructs and proposes a comprehensive quantitative model to address the issue. The CGE model is used to explore the implications of different renewable energy sourced heat shocks on the whole economic system, especially on the CO_2 emissions. To meet the long-term vision of carbon neutrality, decarbonizing the heating sector deserves intensive attention. This study contributes to the understanding of the effectiveness of varied policy instruments, thus benefiting future policy development.

Thirdly, this study also focuses on the methodology of translating economic factors into modelling elements. Despite the multitude barriers, policy interventions, such as subsidy and energy tax, play a significant role in catalyzing the deployment of renewable energy in heating supply, which has not been well reflected in existing energy system models. By aligning the key factors identified in the qualitative analysis（Section 3 with elements of a recently developed CGE model, this study aims at addressing this research gap by incorporating renewable energy sourced heat policy-relevant elements into energy scenario analyses.

1.9 Organization of the Thesis

The present study follows the research flow as below. The research will focus on the existing renewable energy sourced heat policies and implications of different policy instruments on China's climate change goals. A mixed method which combines both qualitative policy analysis and quantitative evaluation is employed. For qualitative analysis, the existing policy framework of China is analysed alongside case studies of regions with high penetration of renewable energy sourced heat. Based on the input from qualitative analysis, a CGE model is specifically tailored for analysing renewable energy sourced heat in China. The implication on CO_2 emissions of the most commonly used policy instruments are evaluated.

Chapter 2 summarizes viewpoints of existing literature, covering both the review of current research on renewable energy sourced heat policies and the evaluation of renewable energy sourced heat policy analysis. Chapter 3 focuses on the mainstream quantitative and qualitative methodologies used in renewable energy policy evaluation and suggests methodologies used in this study. Chapter 4 traces existing renewable energy sourced heat policies in China and globally, elaborating on the framework of China's renewable energy policy framework and the challenges faced. Chapter 5 demonstrates on how to use a tailored CGE model to evaluate different policy instruments. Chapter 6 summarizes viewpoints and key findings through the qualitative and quantitative analysis. Lastly, Chapter 7 summarizes the key findings and conclusions of this study. Figure 1.7 illustrates the entire flow of this study.

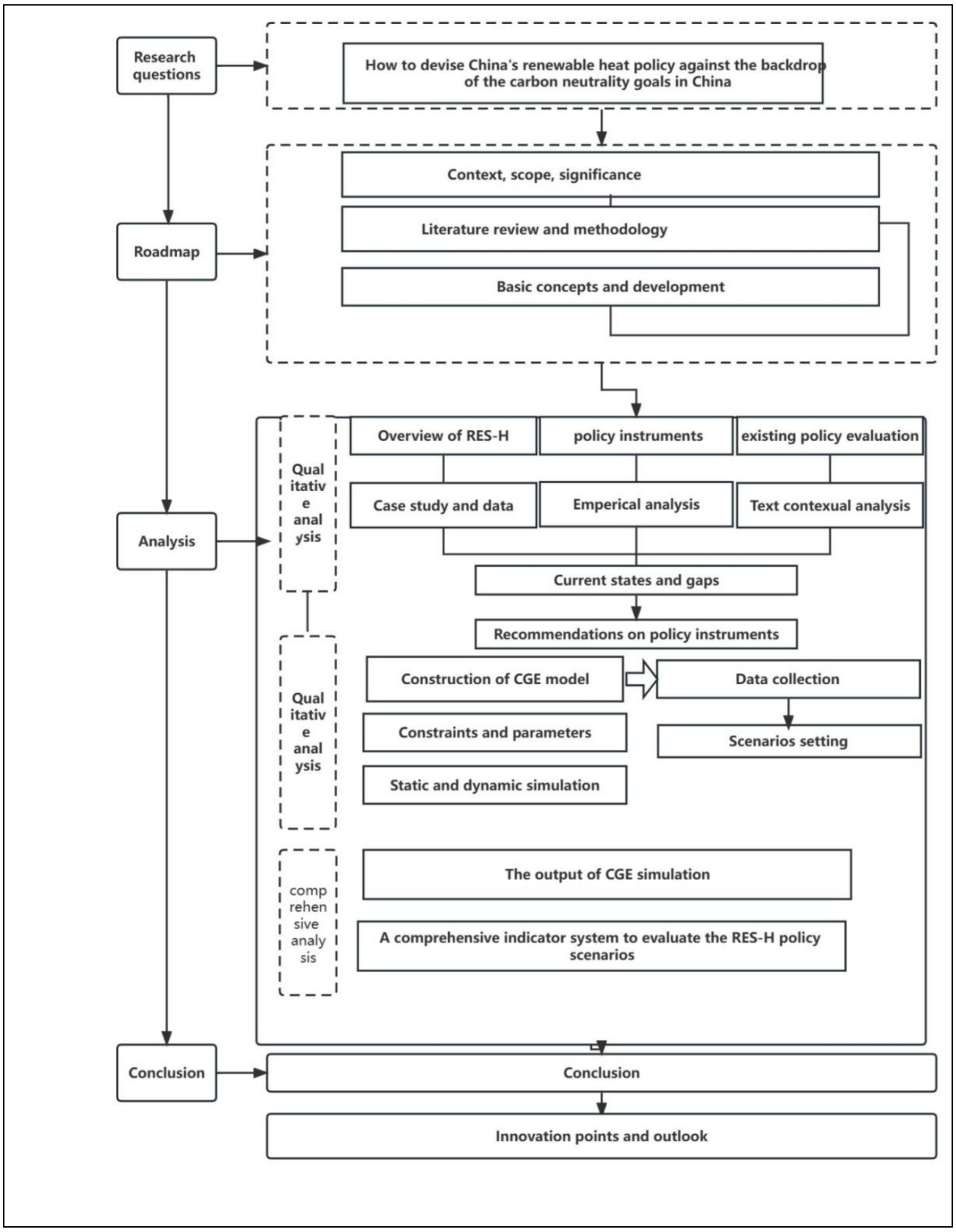


Figure 1.7　　Research flow

CHAPTER 2

OVERVIEW OF RENEWABLE HEAT POLICY

2.1 Introduction

In this chapter, we define key terminologies used in this study, such as renewable heat policies, climate change, and Dynamic Recursive Computable General Equilibrium Building upon this foundation, we review the current status of global renewable heating development and policies, as well as those in China, and summarize relevant case studies. The purpose of this chapter is to provide a comprehensive overview of the field's development, laying the groundwork for subsequent analysis.

2.2 Definition

2.2.1 Climate Change

Climate change refers to long-term changes in the Earth's climate, including changes in temperature, precipitation, and other climatic factors. These changes are primarily driven by human activities, such as burning fossil fuels, deforestation, and industrial processes, which release greenhouse gases (GHGs) into the atmosphere. The accumulation of these gases, such as carbon dioxide and methane, traps heat in the Earth's atmosphere, leading to a warming effect known as global warming (Vlassopoulos, 2012).

According to the Intergovernmental Panel on Climate Change (IPCC), climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. This change can occur due to natural factors, such as volcanic eruptions and solar radiation, however, the current rapid pace of climate change is largely attributed to human activities. The burning of fossil fuels for energy production, transportation, and industrial processes is the primary source of GHG emissions, which are driving the warming of the Earth's climate (Maunder, 2012; Mihaly, 2019).

The impacts of climate change are far-reaching and have serious consequences for the environment, human health, and economies around the world. Rising global temperatures are causing ice caps and glaciers to melt, leading to rising sea levels and increased flooding in coastal areas. Furthermore, changes in precipitation patterns are causing droughts, wildfires, and food shortages in some regions, while increased frequency and intensity of extreme weather events, such as hurricanes and heatwaves, are putting communities at risk.

In order to mitigate the impacts of climate change and prevent further warming of the Earth's climate, it is pertinent to reduce GHG emissions and transition to renewable energy sources. Governments, businesses, and individuals have a role to play in addressing climate change through policies, investments, and lifestyle changes that promote sustainability and reduce carbon footprints (IPCC, 2023).

2.2.2 Renewable Heat Policy

Renewable heat policy refers to a set of regulations, incentives, and strategies put in place by governments to promote the use of renewable sources of heat energy. This policy is designed to reduce the reliance on fossil fuels for heating purposes and to encourage the adoption of cleaner and more sustainable alternatives. Renewable heat policy typically includes measures such as financial incentives, regulations, and targets to promote the use of renewable heat technologies.

One of the key aspects of renewable heat policy is the promotion of renewable heat technologies such as biomass boilers, heat pumps, and solar thermal systems. These technologies harness energy from renewable sources such as the sun, wind, and biomass to provide heat for buildings and other applications. By promoting the use of these technologies, renewable heat policy aims to reduce GHG emissions, improve air quality, and enhance energy security.

2.2.3 Dynamic Recursive Computable General Equilibrium (CGE) model

A Computable General Equilibrium (CGE) model is a type of economic model that is used to analyse the effects of various economic policies on an economy as a whole. It is a mathematical representation of an economy that takes into account the interactions between different sectors, households, and government entities. CGE models are widely used by policymakers, researchers, and analysts to study the impacts of changes in tax policies, trade agreements, and other economic variables (Holmøy, 2016).

The origins of CGE models can be traced back to the 1950s, when economists began to develop large-scale mathematical models to analyse the effects of policy changes on the economy. The first CGE model was developed by Nobel laureate Wassily Leontief in the 1950s, and since then, the methodology has been refined and expanded by a number of economists and researchers (Zhao et al., 2022).

CGE models are based on a set of equations that represent the relationships between different economic variables, such as consumption, production, and investment. These equations are solved simultaneously to determine how changes in one variable will affect the others. The models take into account factors such as input-output relationships, factor markets, and international trade flows.