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Renewable Heat Policy in China: Development, Achievement, and Effectiveness

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Abstract: Heat is the largest energy end-use sector, accounting for half of the global final energy consumption and more than 40% of energy-related CO_2 emissions. China produces more than one-quarter of global heat. Policy interventions are of great necessity to overcome the economic and non-economic barriers the sector encounters. The purpose of this study is to explore the evolution history of China's renewable heat policies over the last 20 years and to assess the effectiveness of the current policy system. The evolution of the policies is strongly linked to China's socio-economic background and is driven by various factors at each stage. A policy intensity index model is formulated to further dive into the dynamic characteristics of renewable heating. The results indicate that regulation-based instruments are always preferred, with varying degrees of lag for the other three types of instrument. Since the inception of the clean heating program in 2017, the intensity of renewable heating has increased dramatically, revealing that renewable heating has received increasing policy attention and is gradually becoming a key pillar in the context of climate change targets.

Keywords: renewable heating; policy; instrument

Citation: Xiong, C.; Hassan, M.S. Renewable Heat Policy in China: Development, Achievement, and Effectiveness. *Sustainability* **2022**, *14*, 9297. https://doi.org/10.3390/su14159297

Academic Editors: Luis Hernández-Callejo, Jesús Armando Aguilar Jiménez and Carlos Meza Benavides

Received: 15 June 2022
Accepted: 25 July 2022
Published: 29 July 2022

1. Introduction

China has committed to peaking carbon emissions by 2030 and achieving carbon neutrality by 2060 ("30/60 targets"). Reaching the 30/60 targets demands a dramatic scaling up of clean energy. Heating is the largest energy end-use sector, accounting for half of the global final energy consumption and more than 40% (13.1 Gt) of worldwide energy-related CO_2 emissions in 2020 [1]. More than one-quarter of global heat is produced and consumed in China, where the heat sector remains heavily reliant on fossil energy [2]. Renewable energy plays a critical role in decarbonizing and providing a greener energy supply option [3]. However, for a long time, renewable energy sources of heating (renewable heating) have been neglected in favor of a focus on renewable electricity, with less than 10% of energy supply coming from renewable energy sources.

The deployment of renewable energy in the heating sector should be accelerated to meet 30/60 targets, which will also bring additional benefits, including decreasing air pollution emissions and enhancing energy security [4]. However, there are still many obstacles to overcome, such as high capital costs, low prices of fossil fuels, and subsidies for fossil fuels. Policy intervention is needed to overcome the economic and non-economic barriers faced by the sector. In the past 20 years, China has already formulated some policies to support the deployment of renewable energy in the heating sector; however, there have been few systematic reviews of the existing renewable heating policies, and the key factors in designing the policies are still not well understood.

Besides, the majority of literature on renewable heating focus on specific renewable modes, e.g., geothermal, biomass, wind power heating etc. [5–7], analysis of the effectiveness of renewable heating systems [8–11], and evaluation of the impact of policies on

energy use, climate change, and technology penetration [12–14]. These efforts have assisted in gaining a better understanding of the renewable heating system; however, the policy itself is rarely studied, especially when it comes to the implementation level. In China, policy implementation is crucial due to its special administrative structure [15]. Zhang et al. evaluated the energy saving and environmental policies in China, and proposed that the effectiveness of these policies are largely determined by the implementation level factors, including the instruments applied and the intensity of the policy itself [16,17]. However, few studies have evaluated renewable heat policies from these perspectives.

To fill the aforementioned research gaps, this study covers three aspects. Firstly, the development and framework of renewable heat policies formulated in the last 20 years are reviewed to construct a broad picture of the policy system. Secondly, the policies are clustered according to the instruments applied to bolster a quantitative analysis and obtain an in-depth insight into the dynamic development process. Finally, suggestions to establish a more efficient renewable heat policy system are provided. The results of this study will contribute to a comprehensive understanding of China's renewable heat policy and will shed light on policy design and implementation in the future.

2. Methods

In this study, a systematic review of renewable heat policies in China, spanning from 2000 to 2021, is conducted to understand the framework of China's renewable heat policy and to determine the key drivers in policy making. The review approach is developed by referencing several studies, including Zhu Bei et al. [18], Liu Junxia et al. [15], and Chul Kim [19].

To quantify the effectiveness of existing policies, a policy intensity index (PII) model is employed. A policy intensity index is developed based on the game theory of public policy to quantify the impact of policies. The index was first developed by Libecap [20] in 1978, and then widely used to quantify policy effectiveness. The structure of the PII in this paper is established based on previous studies concerning China's energy saving and clean heating policies [16–18,21], and specific modifications are made to precisely reflect the characteristics of renewable heat policy. The modification contains 2 aspects. Firstly, the score scope is narrowed down to 3 degrees. Secondly, the policies are classified into 3 categories instead of 5 categories, to simplify the evaluation.

Table 1 shows a breakdown of the index indicators, which includes 2 primary aspects: issuance level and target level. The policy's authority level is measured by the level of issuance. The issuance level aims to measure the authority degree of the policy through 3 sub-indicators: document type, issuer level, and coverage of the policy. The target level includes 2 indicators, the refinement and the duration of the targets, with the purpose of assessing the stringency degree of the targets in the policy. Each sub-indicator is endowed with the same score rules, from 1 to 3.

In terms of data processing, we gathered policy documents from official government websites, such as the official websites of the state council (SC), the National Development and Reform Commission (NDRC), the Ministry of Ecology and Environment (MEE), and relevant policy databases. A total of 146 relevant policies were collected. The keywords for text analysis included "policy," "regulation," "renewable heating," "geothermal," "biomass," "wind power heating," "clean heating," and "solar heating". Screen criteria was identified to ensure that the policy type was in the form of law, regulation, opinion, measure, or notice. The collected policies were standardized for further quantitative analysis by issue time, issuer, the number of issuers, target type, coverage, etc. The timeline ranged from 2000 to 2021, with the consideration that few policies were released before 2000.

Table 1. The breakdown of PPI indicators.

Indicator	Sub-Indicator	Score Rules
1. Issuance level	1.1. Document type (P1)	➢ Law: 3 ➢ Strategy, guidance opinion, plan, and action plan: 2 ➢ The announcement, notification, and implementation measures: 1
	1.2. Coverage (P2)	➢ National level: 3 ➢ Provincial level: 2 ➢ City level: 1
	1.3. Issuer level (P3)	➢ State council: 3 ➢ Ministries (more than 3): 2 ➢ Less than 2 ministries or provincial governments: 1
2. Target level	2.1. Refinement of targets (P4)	➢ Specific quantitative targets: 3 ➢ Only overall targets: 2 ➢ Only qualitative targets: 1
	2.2. Duration of targets(P5)	➢ More than 5 years: 3 ➢ 3–5 years: 2 ➢ One year or less: 1

After each indicator was scored, the policy intensity for a policy was calculated by multiplying all the sub-indicators. The model is shown in the following formula.

$$P_i = \sum_j^N \left(P1_{j,i} \times P2_{j,i} \times P3_{j,i} \times P4_{j,i} \times P5_{j,i}\right),\ i = [2000, 2021] \quad (1)$$

P_i represents the policy intensity of year i, while j represents the ordinal number of the policy in year i. $P1_{j,i}$ to $P5_{j,i}$ represent the score of the sub-indicator in a specific year of policy j.

3. Development of China's Renewable Heat Policy

3.1. Architecture of Renewable Heat Policies in China

China's current renewable heat policy system has been formed from scratch after more than 20 years of efforts. The architecture of the system is illustrated in Figure 1, to elucidate the inner relationship of the policies. Generally, policies can be classified into several levels. The first level is law, which lays out a fundamental legal framework for the development of renewable heating. The second level is medium- to long-term strategies or plans. The third level focuses on short-term comprehensive plans, including conventional plans and unconventional plans. The fourth level is sub-plans and special policies. The fifth level refers to local plans and policies.

China introduced the Renewable Energy Law in 2005, and since then renewable energy has become a preferential area for energy development. Renewable law lays a legal basis for renewable heating development. To implement the renewable heating law, central and local governments have formulated a series of policies.

Under the renewable law, medium- to long-term strategies are made. "The Medium- and Long-Term Renewable Development Plan" [22] and the relevant climate and environment strategy mainly addressed the principles and priority tasks for making short-term national renewable energy plans in China.

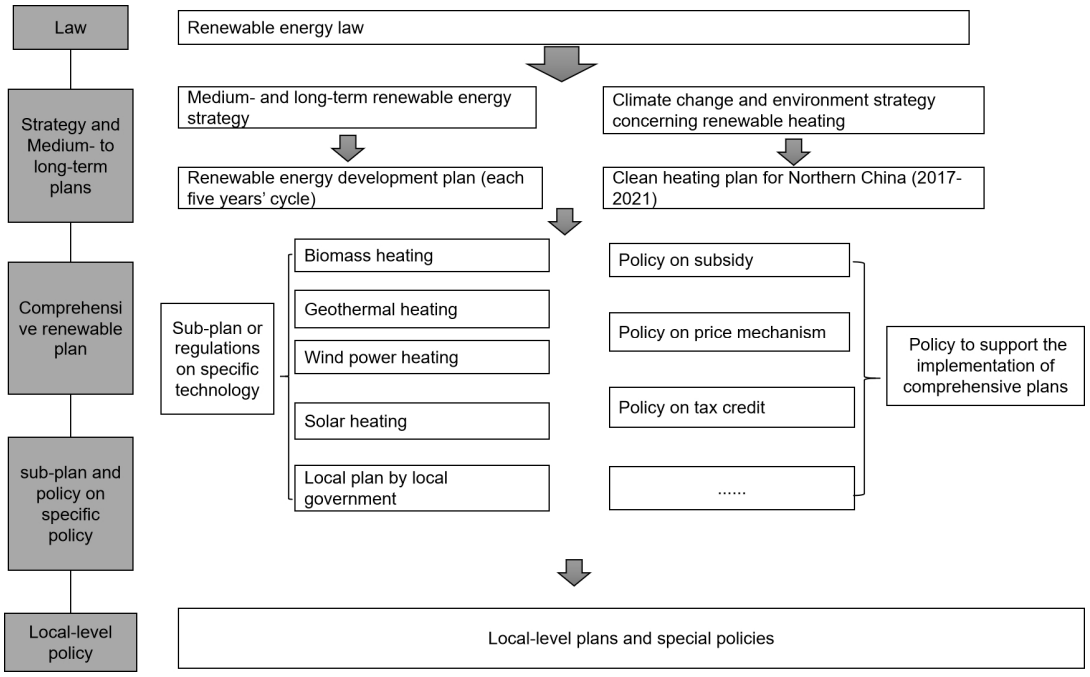

Figure 1. The structure of the renewable policy in China.

Based on strategy and high-level guidance, central governments usually make conventional plans to guide the next five years of development. The first renewable energy development plan was issued in 2012, and China has since began to promulgate a renewable development plan for each five-year period. These plans generally include mandatory goals that should be achieved by the end of the fifth year. Alongside conventional plans, some unconventional plans were also promulgated to address important and urgent issues. In 2017, the Clean Heating Plan for Northern China (2017–2021) (clean heating plan) was released jointly by nine ministries to facilitate the transformation of clean heating, and to control air pollution caused by coal-fired boilers [23]. The implementation of the clean heating plan spanned three years until the end of 2021 and covered "2 + 26" cities in Northern China.

The targets in these comprehensive plans are usually broken down into more specific targets and presented in sub-plans with specific measures. China has issued special plans for geothermal energy heating, biomass energy heating, renewable electricity heating, solar water, and heating policies [24–28]. Additionally, it is of significance to engage in the implementation of comprehensive plans and supporting policies, such as subsidies and tax credits, to show sufficient support and attention.

Local governments commonly release renewable heat policies according to local conditions under the umbrella of national policies. For example, Inner Mongolia issued the "Notice on wind power for heating to support the utilization of wind power for heating in winter seasons" [29]. Furthermore, local governments are also encouraged to formulate local standards to enhance the implementation of renewable policies and regulations. As of 2015, more than 28 provinces had already issued compulsory regulations requiring new buildings to install solar heating systems [30].

3.2. The Development of Renewable Heating in China

When the cost of solar water heating systems dropped significantly in the 2000s, renewable heating started to receive more attention from policymakers [30]. Since then, progress in policies has been accelerated to push forward the deployment of renewable energy in the heating sector. The evolution of renewable heat policies has been closely associated with the socio-economic context of the last 20 years [24]. The development of

renewable heating policies can be divided into four stages, as shown in Table 2. The key drivers and the role of renewable heating are different in different stages.

Table 2. The four stages of renewable heating development.

Projection Period	Stage 1	Stage 2	Stage 3	Stage 4
	2000–2013	**2013–2016**	**2017–2020**	**2021–Present**
Key driver	Increasing demand for consumption	Air pollution issues	Clean heating program to achieve higher air quality	New climate change goals and the need for the energy transition
Key policy	Renewable law, solar heating incentives, and compulsory standards	12th and 13th five-year plans for renewable heating	Plan for clean heating in Northern China (2017–2021)	Notice on implementing renewable heat according to local conditions
Policy goals	No specific goals for renewable heating	Quantitative goals: substitution of coal achieving 100 million by the end of 2015 and 400 million m^2 for solar heating 580 million m^2	Quantitative goals: one billion square meters of geothermal, 2.1 billion square meters of biomass, and 50 million square meters of solar energy	Quantitative goals: the scale of geothermal heating, biomass heating, biomass fuels, solar thermal utilization, and other non-electric utilization reached 60 million tons of standard coal by the end of 2025
Role of renewable heating at the policy level	A supplement to energy use especially in household	A supplement when coal is replaced	One of the main sources of clean heating supply	Imperative solution for climate change goals

- Stage 1: driven by household demand, from 2000 to 2013

Since 2000, China has undergone rapid urbanization, along with a rapid increase in the application of domestic solar water systems. Strong demand from the consumption side drove the significant growth of the installation of solar water heating systems, which achieved 323.1 million m^2 by the end of 2012 [4]. Incentive measures, i.e., subsidies, tax credit, and compulsory standards greatly promoted the deployment of solar heating. The solar heating market expanded rapidly with strong responses, since solar heating was integrated into the energy saving livelihood program (China started to implement the energy saving livelihood program in 2012, by providing subsidies for energy-saving products, including solar water products). This required direct delivery of subsidies for households that were equipped with solar heating systems. However, the year 2014 witnessed the beginning of a decline in the growth rate due to the expiration of the program. The market progress of solar heating is described in Figure 2.

In this stage, solar heating dominated the renewable heating market, with other renewable heating technologies accounting for little market share. This stage is marked by an initial stage of renewable heating, with household demand as the key driving factor.

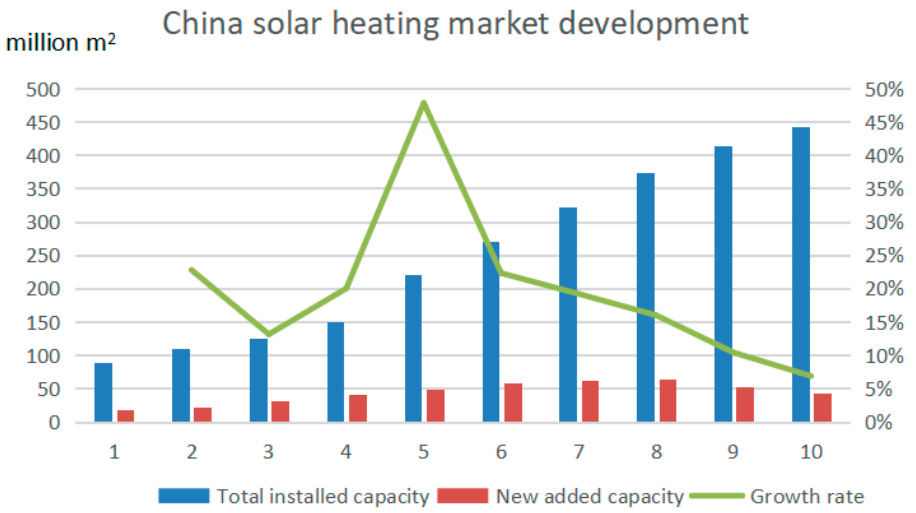

Figure 2. The development of the solar heating market in China.

- Stage 2: driven by air pollution issues, from 2013 to 2017

In 2013, extreme haze weather hit northern areas of China with a high frequency. The increasing environmental awareness of the public and concerns over air pollution instigated heating reform focusing on clean energy transition [31]. In 2013, the state council (SC) issued the Air Pollution Prevention and Control Action Plan [32]. Following this, regulations on the substitution of coal for residential heating became a vital part of national air pollution control and environmental supervision. Moreover, renewable heat policies were introduced accordingly in this stage, focusing on specific technologies, such as biomass and geothermal energy. In 2013, a special policy titled "Guidance opinions on promoting utilization of geothermal energy" [24] was released, clarifying the main objectives, key tasks, and measures required to foster the geothermal heating industry. It is also worth noting that the first renewable heating target for the whole country was confirmed at this stage. In the 12th Five-Year Renewable Energy Development Plan [33], a quantitative indicator for renewable heating, namely the amount of substitution of fossil energy, was established. Subsequently, in the 13th Five-Year Renewable Energy Development Plan, the targets were further enhanced, from 10 billion tce by 2015 to 15 billion tce by 2020 [34].

At this stage, policies on renewable heating began to be more vigorously implemented, and specific quantitative targets for renewable heating development were determined for the first time. The primary policy measures in this stage were aimed at providing resolutions to air pollution issues, and renewable heating was deemed as a supplementary solution to replacing coal.

- Stage 3: driven by demand of higher air quality

In 2017, 10 ministries and commissions jointly promulgated the Plan for Clean Heating in Northern China (2017–2021) [23], which formally defined the energy sources of clean heating, including geothermal energy, biomass, solar energy, natural gas, electricity, industrial waste heat, clean coal combustion, nuclear energy, etc. In the policy, an ambitious target was proposed, striving to achieve a 50% clean heating rate by 2019 and 70% by 2021. Furthermore, renewable heating was for the first time identified as the main source of clean heating energy rather than playing a supplementary role in the previous stage. Specific goals were given for each renewable heating technology, i.e., one billion square meters for geothermal energy, 2.1 billion square meters for biomass, and 50 million square meters for solar energy by the end of 2021.

To ensure the implementation of the plan, regulations on subsidies and price mechanisms were also released at this stage. In 2017, the Ministry of Finance provided subsidies to 43 pilot cities, with an annual subsidy of one billion RMB for municipalities, 700 million RMB for provincial capitals, as well as 500 million RMB for other cities [35]. Following

this, the National Development and Reform Commission (NDRC) issued a policy titled "Opinions on Clean Heating Price in North China" to overcome the issue of price distortion, clarifying that renewable energy should be given high priority in heating energy supply and linkage of electric heating, wind, and solar power generation curtailment should be established [36]. Thereafter, the 13th Five-Year Development Plan of Geothermal Energy [37] specified the goals and strengthened the measures, in which specific geothermal modes, shallow geothermal systems, and hot rock geothermal systems were introduced to solve the problem of winter heating where applicable. Meanwhile, in the 13th Five-Year Development Plan of Biomass Energy [26], biomass heating, especially biomass co-generation, was highlighted to supplement the energy supply with regard to the implementation of "coal to gas" or "coal to electricity" policies.

At this stage, renewable heating was formally integrated into the clean heating system as a main source of energy supply, rather than a supplement. Applying more diverse policy instruments could contribute to ensuring the implementation of the clean heating plan.

- Stage 4: driven by ambitious climate change goals, 2021–

In 2021, a comprehensive policy titled "Notice on advancing the development of renewable heating according to local conditions" was launched [38], consisting of six aspects: (1) release special plans for renewable heating, including specific renewable heating goals aligned with the requirements of climate change goals; (2) promote various types of renewable heating technologies according to local conditions; (3) continue promoting pilot demonstration work and major project construction; (4) guarantee policy support of renewable heat; (5) strengthen R&D support for key technical equipment; and (6) improve the government management system for renewable heat. The policy symbolized the significant achievements of clean heating policies in China and initiated a new era of renewable heating development. The 30/60 targets served as the dominant driver for this stage. Subsequently, a series of policies concerning renewable heating were released. The most recent policy is "Several opinions on promoting the development and utilization of geothermal energy" [25], jointly issued by eight ministries, which highlights the importance of geothermal utilization.

In summary, the year 2021 witnessed the transformation of renewable heat policy with the release of a comprehensive renewable heating program. This indicates that renewable heating in China has been formally integrated into the energy transition system as a key measure to address climate change.

4. Evaluation of Renewable Heat Policy

In China, policies have varying impacts according to the authority level of the issuer. Regulations issued by the state council generally have the highest authority, followed by regulations or policies jointly issued by multiple ministries. Policies released by the signal ministry or province (autonomous region, municipality) have the lowest authority. Furthermore, the efficacy of a policy is also greatly related to the document type, i.e., law has the highest efficacy, followed by strategy.

A policy instrument provides the link between policy formulation and policy implementation. The instrument used in a policy has a significant impact on how well it is implemented [39]. Policies can be divided into four categories using the instrument applied: regulation-based policy, fiscal instrument-based policy, price mechanism-based policy, and financial instrument-based policy. Regulation-based instruments include targets, planning, compulsory standards, etc. Fiscal instruments commonly include subsidies, grants, tax credits, etc. Price-based instruments include heat-trading mechanisms, carbon markets, etc. Typical financial instruments are bonds, loans, and direct equity investments [4].

In this section, renewable heat policies are evaluated from two perspectives. First, we focus on the instrument in the policies to find out how the policy is implemented. Second, PII is used to further understand the intensity of the existing policies and their efficacy.

4.1. The Instruments of Renewable Heat Policies

In this paper, the cumulative number is used to quantify the instrument applied in policies. To be specific, policies are classified according to the type of instrument and a specific instrument that appeared in a specific year was counted in the subsequent years. Policies that use several instruments are counted into primary instrument types to avoid double counting. The cumulative numbers of the four types of policies according to instruments applied from 2000 to 2021 are illustrated in Figure 3.

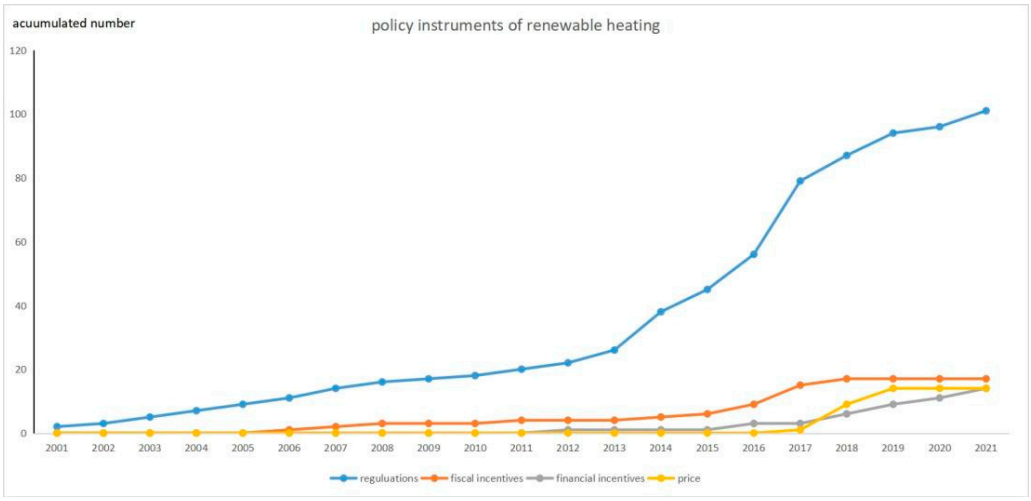

Figure 3. Development of policies according to instruments.

Overall, it demonstrated an upward tendency of all four types of renewable policies since stage 2, particularly for regulation-based policies, which increased from 20 to more than 100 over seven years. Comparatively, it can be seen that the other three types all showed some degree of delay. The amount of fiscal incentive policies has grown moderately since 2015, while the price and financial instrument-based policies began to increase steadily only after 2017.

In terms of the amount of the four types of policies, regulation-based policies are largest with a share of approximately 70% by 2021. Fiscal incentives began to increase in 2017, leading to a share of 11% by the end of 2021, with the remaining two types at less than 20%. Regulation-based policies are preferred, with an amount much higher than the other three instruments, showing a structured imbalance in the application of different instruments.

4.2. Evaluation of Policy Intensity

To further illustrate the dynamic changes in renewable heat policies over the last 20 years, the policy intensity index from 2012–2021 was gained using the model introduced in Section 2. The results are shown in a bubbling figure (Figure 4), where the size of the bubble represents the intensity of the policies of a specific year.

It can be seen that the intensity of the four types of policies showed different patterns, among which regulation-based policies showed the strongest intensity of all four stages. The intensity of regulation-based policies reached the highest level in the year 2017, which can be attributed to a series of policies issued by high-level authorities, including the SC. Fiscal relevant policies followed after and financial instrument-based policies had the lowest intensity. The years following 2017 witnessed an increase in the intensity of the four types of policies, indicating the increasing political will for renewable heating from the policy maker.

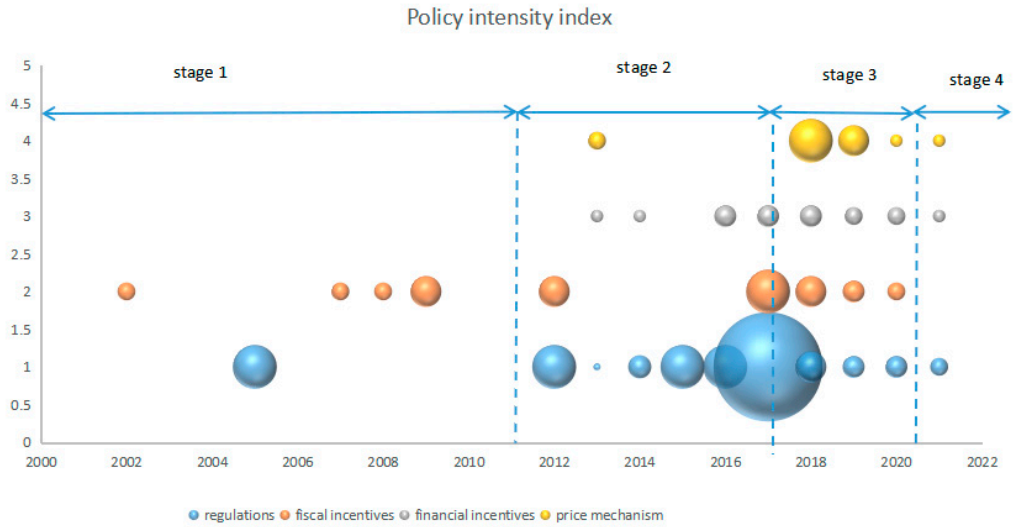

Figure 4. Policy intensity index of the four types of policies.

For the four types of policy instruments, the following can be found if Figures 3 and 4 are combined:

Regulation-based policies dominated in the policy system, which were both largest in amount and strongest in stringency. The high-frequency application of regulation-based instruments in renewable heat policies reflects that the renewable heating market is still primarily driven by governments and is still at an initial stage, where mandatory regulations are greatly needed. However, it is not recommended that regulation-based policies are applied long term, due to the lack of flexibility and cost effectiveness.

Fiscal incentives have been implemented since 2017 when the clean heating program was initiated, marking a major step. However, the incentive options are limited, and subsidy is the most common approach. Fiscal instruments can play a great role in the initial stages by supplementing the capital cost, but put great pressure on the government. More diverse instruments can be deployed when providing fiscal support. One example is the renewable heating incentive (RHI) from the United Kingdom, which is similar to the tariff mechanism in the generation market. The tariff mechanism can be more result-orientated and flexible compared to subsidy.

Market-based policies, including price mechanism and financial incentives, are least used. Market-based policies are seen as the most cost-efficient way to foster a renewable market by internalizing the environmental and economic cost. The application of market-based policies should be greatly accelerated.

5. Conclusions and Suggestions

5.1. Conclusions

China's renewable heat policies have advanced quickly in the last two decades. Numerous policies have been implemented. However, few studies have examined the evolution of these policies. We used the PII model to present the dynamic changes in the renewable heat policies and three conclusions were summarized as follows.

Firstly, we systematically reviewed and illustrated the overall development of renewable heat policies from 2000 to 2021. China has established a renewable heat policy system, which consists of five levels of policy, each with different power and authority. The top levels are law, strategies, and plans, which provide macro guidance for long-term development. The middle levels are comprehensive policies and regulations in the form of five-year plans, special plans, etc., to further specify targets and measures. The policies at the bottom levels are commonly designed for guiding implementation, including supporting policies with incentives, special plans, or regulations, targeting specific renewable heating technology models and local policies.

Secondly, the 20 years were divided into four stages. In stage 1, the main driver was the increasing heating demand from households, when the market for solar water heating soared quickly. In this stage, regulation-based policies, such as compulsory standards, pushed the expansion of the market. Furthermore, incentives also played an important role. The second stage began in 2013. In this stage, issues with air pollution pushed the development of renewable heating, with more political attention paid to renewable heating to supplement the coal-to-gas program in fighting against air pollution. In 2017, China initiated its clean heating plan, when renewable heating began to formally integrate into the clean heating system. The fourth stage was driven by new climate change goals. In this stage, the development of renewable heating became a certainty. The renewable heating development of the past 20 years has a strong link with the socio-economic context, showing various features in different stages. Thirdly, to further dive into the renewable heat policy, we classified the existing renewable heat policies into four categories according to the instruments applied. The results showed that the structure of the four instruments were in disproportion, with regulation-based instruments the most preferred. While the government began to apply other instruments to overcome price distortion and other issues, the impact is still limited. The number of policies with all four instruments increased dramatically since stage 3, when China began to implement its clean heating program. To enhance the implementation of the 30/60 targets, the application of market-based policies are greatly needed.

5.2. Policy Suggestions

To further accelerate the deployment of renewable energy in the heating sector, the following suggestions are proposed:

Firstly, multiple barriers in the renewable heating sector call for a range of policy instruments, often in combination. Regulation-based instruments, which generally lack flexibility and cost-effectiveness, should be supplemented by other policies, especially market-orientated policies. The application of regulation instruments can be strengthened by increasing the application of other types of policy instruments. Instrument diversification is required to strike a balance between cost, adaptability, and efficacy.

Secondly, the incentive system for renewable heating needs to be strengthened. The externality of renewable heating can be partially compensated by incentives. Instead of relying solely on subsidies, the government can use a variety of incentives, such as tax breaks, tariffs for renewable heating sources, etc., to alleviate the financial load. Additionally, innovative measures, such as result-based incentives and loan guarantees, can also be applied when applicable.

Thirdly, market-orientated instruments should be further enhanced in policies. Carbon market and green finance instruments have great potential in further enhancing the development of the renewable heating market. Financial instruments should be more embodied in future policies, such as green loans and green bonds.

Finally, policy coordination should be further strengthened. Coordination can improve the efficiency of resource allocation, as well as avoid unnecessary conflict in implementation.

The present work provides a first and comprehensive review of China's renewable heating policy at the national level. Further research regarding the role of the policy's executor, the local government, would be of great help in understanding the effectiveness of renewable heating. In addition, a considerable amount of work is needed to evaluate the impact of renewable heating on energy transition and carbon emission, to examine the evolution of household heating patterns, and to explore the possible demand-side management option using an experimental approach.

Author Contributions: Writing—original draft preparation, C.X.; supervision, M.S.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

Renewable heating	Renewable energy source for heating
IEA	International Energy Agency
SC	State Council
MEE	Ministry of Ecological Environment
MOF	Ministry of Finance
MOHURD	Ministry of Housing and Urban-Rural Development
NDRC	National Development and Reform Commission
NEA	National Energy Administration
MLR	Ministry of Land and Resource
PII	policy intensity index

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