The development of energy conservation policy of buildings in China: a comprehensive review and analysis

Article

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The development of energy conservation policy of buildings in China: A Comprehensive Review and Analysis

Shiyu Han[a*], Runming Yao[a,b], Nan Li[b*]

[a,] University of Reading, School of the Built Environment, Reading, the United Kingdom

[b] Chongqing University, School of Civil Engineering, Chongqing, China

Abstract

Energy conservation policies of buildings (ECPB) comprise combined governmental forces of national plans, laws and mandatory regulations of buildings, which have proved important contribution in improving energy efficiency and reduce carbon emissions. However, increasing the effectiveness of national policy is a challengeable task due to the complexities of historical, social, economic and environmental problems involved. Future policy designs of ECPB should be very careful and scientific from retrospect of their appeared achievements and problems from policies implemented in history. It is therefore important to fully understand the development of the ECPB, of particular note is the way the policy system has been progressively developed over time, which have not been formally and comprehensively studied yet. In this research, a chronological review method is first developed to review, retrospect and analyse the historical development, policy content, and policy effectiveness of China's building energy conservation. The aim of this review paper is to provide comprehensive information and analytical insights for both policymakers and scholars of building energy conservation researches. From this review research, the milestone policy and achievements of ECPB historical development are evaluated, and their policy barriers and possible improvements are discovered. Accordingly, this method can provide important knowledge to support and improve future policy design and policy system development in building energy conservation.

Keywords

Energy Policy, Energy Conservation, Building Energy Efficiency, Historical Development

Abbreviation

ECPB -- Energy Conservation Policies of Buildings

GPEBE – Governmental Policies of Energy, Building and Environment

BEES – Building Energy Efficiency Standards

FYP – the Five-Year Plan

HVAC – Heating, Ventilation and Air-Conditioning

SC & C – Server Cold and Cold

HSCW – Hot Summer and Cold Winter

HSWW – Hot Summer and Warm Winter

CGBL – China Green Building Label

EPC – Energy Performance Contracting

TGPUG – Technical Guidelines of Passive, Ultra-low energy consumption, and Green buildings

TSNZE – Technical Standard for Nearly-Zero Energy building (as GB/T 51350-2019)

RED – Renewable Energy Directive

RO – Renewables Obligation

1. Introduction

China has undergone extensive economic development over the last four decades but is increasingly hitherto facing serious issues of energy scarcity. The country is also facing huge challenges in respect of environmental quality due to heavy pollutions resulting from rapid industrialisation and ongoing processes of urbanisation. The broader impact on climate change is a global concern.

Among many aspects of sustainable development, energy and carbon emission are perhaps the most essential themes. In particular, building energy efficiency is the declared primary mission of China's energy and carbon reduction programme [1]. Statistics show that the building sector currently accounts for approximately 27.5% of total national energy consumption, and is likely to increase to 30% in the future [2]. Moreover, from 1978 to 2012, the rate of urbanization in China has increased from 17.9% to 52.6% [3], and it continues to increase at a seemingly exponential rate. With a huge large population base and ever-increasing growth, China's urbanisation process places ever increasing demands of buildings. Research [4] reveals that there is an increasing demand in energy consumption for heating, cooling, ventilation and lighting to improve indoor environmental quality.

Government policy seeks to establish a coherent set of principles for the purposes of guiding decision making, and achieving rational outcomes [5]. In the energy sector, the energy conservation policies of buildings (ECPB) comprise a combination of national plans, laws and mandatory regulations for energy conservation [6]. They are widely accepted as having been effective in improving national energy efficiency and reduce carbon emissions [7-9]. Policy in the context of rapidly increasing energy consumption China has consistently sought to implement a top-down administrative energy conservation measure over the last four decades. This mechanism has been continuously developed for years and achieved significant reduction goals in energy consumption and pollution emission. The Chinese government has set up the 65% reduction target of total carbon emission based on the protocol negotiated in the 2016 Paris Agreement [10]. In the history of national development, China's energy conservation policy mechanism has significantly played an important role [11].

Yet the current situation of energy efficiency in building sector is not optimistic due to its rapidly increased urbanisation rate, population, and people's demand of improving indoor environmental quality. Especially, in China's Hot Summer and Cold Winter climate zone and rural area, the majority of people still live under very poor conditions of indoor thermal environment [12]. With their increasing economic income and demand of better living quality, the energy consumption potential for China's future could be enormous. Reflecting back to current governmental energy policies and building energy standards, there are still plenty of improvements needed to achieve for the objectives set ambitiously in energy and carbon emission reduction [2]. The question remains regards the effectiveness of future energy conservation policy of buildings. Therefore, there is a need to gain new insights through reviewing and analysing the comprehensive and detailed information of the previous implemented ECPB, while the situation is serious, and the majority of current policy review studies are not comprehensive enough and cover the long timeline in whole country scale.

2. Literature review of previous ECPB studies

This paper aims at the development of an approach to conduct an integrated review of energy conservation policies of buildings and their effectiveness, and to provide valuable information and analytical insights for both policymakers and scholars of building energy conservation. Therefore, the literature review of previous ECPB studies is required to find the research gap and policy barriers in the field.

2.1. Lack of coherent analysis of ECPB development history

To review such massive amount of literature during 40 years, the archival study is an effective method [5, 13] and has been widely used in a comprehensive informative review studies for policy [14, 15]. It is proven that important insights can be gleaning by considered how the ECPB were being developed over time [16, 17]. As the limitation of previous literature of ECPB archival study papers, relatively few archival ECPB researches adopted a chronological review of the historical events which drove ECPB development. For example, Li and Shui [18] inferred some limitations of current building energy conservation standards; Hong [19], Yan et al. [20] reviewed the building ECPB content and compared with policies issued in other developed countries. However, their statements might be too general without enough support from comprehensive content and data analysis.

Similarly, Yang et al., Li et al. and Zhang et al. [21-23] reviewed many green building assessment codes in different countries and compared their sustainability content with limitations without involving enough country background, social and economic aspects. Likewise, three law-based studies Peng and Liu [24], Jiao and Boons [25], Zhao et al. [26] respectively analysed three single energy laws of their clause development and implementation effectiveness, but these studies did not consider much of the situation and strategy of country development, either not enough thinking of national ECPB that could affect the formulation of policies.

In general, there remains an absence of causal relationship between national development of economic, energy and environment, also without any holistic reviews of the long-term historical development of ECPB in China. Compared with relevant historical studies of ECPB packages as Economidou et al. [27] mentioned for European countries, for the last four decades, the ECPBs issued in China are chaotic without appropriate ordering due to their complex revisions and update editions. Based on the research objectives, this study should order the ECPB issued chronologically. Besides, as the governmental policies issued are usually affected by external reasons, the important historical events which related with energy policies should been also collected and arranged with the timeline.

2.1. ECPB classification: GPEBE and BEES

Rather than traditional policy review studies that focus on only one type of ECPB, this research requires massive amount of policy content to be reviewed, which cover all the policy types in the country. Therefore. considering the complexity and characteristics of implemented policies over the last four decades, ECPBs can be classified into two categories, as one is the general policies issued by the central government as **Governmental Policies of Energy, Building and Environment** (**GPEBE**). These policies were issued

by the central government unit as the State Council, which provide very general guidance of national energy development strategy for a period of time. For the building sector, the ECPB for buildings has been developed into a more specific and independent system during the GPEBE development called national **Building Energy Efficiency Standards** (**BEES**). In China, these policies are core policy for energy conservation of buildings. Issued by the Ministry of Housing and Urban-Rural Development, they have much more detailed and clear engineering approaches and technical practices [28]. While GPEBE are still presenting directions and objectives for national energy conservation, building designers and policymakers in building energy aspect of China now heavily rely on these standards for their designs and studies in building energy consumption. Respectively, both GPEBE and BEES are ordered, classified, reviewed and discussed in a chronological timeline in this study.

GPEBE are policies usually issued by the national administrative and legislature offices. They routinely contain massive amounts of information about every aspect of China's development. In this paper, majority important GPEBE published by the Chinese government are reviewed and analysed. In the energy, building and environment sectors, the most important governmental agencies and their functional roles of policymaking are summarized and listed below in **Table 1.**

Table 1
Main governmental units of building energy policy system in China

Full name	Abbreviation	Role in the policy system	Feature
The State Council	GOV	Central administrative unit. Provides overall objectives and general directions	General
The National People's Congress and its Standing Committee	NPC	Central legislature unit. Decision-making of general national policies and plans of laws	General
National Development and Reform Commission	NDRC	Provides the grand designs of national plans and detailed objectives	General
National Bureau of Statistics	NBS	Provides national statistics for general policymaking and evaluation	Detailed
Ministry of Science and Technology	MOST	Provides plans and related appropriation funds (Ministry of Finance) for research institutions and universities	Detailed
Ministry of Housing and Urban-Rural Development (as Ministry of Construction before 2008)	MOHURD	Main governmental office of building energy policies. Provides very specific and detailed guidelines and plans for further social actions and studies to acquire the objectives (as BEES)	Detailed
Ministry of Ecology and Environment	MOEE	Provides environmental situation data and plans of pollution-reduction objectives	Detailed

In general, policymaking commences with very general policy directions and guidelines (known as the Five-Year Plans). These lay out the basic objectives required to be met within specified target times. It is then the responsibility of individual ministries to arrange the detail objectives and plans such as local policies and sectoral standards.

For BEES issued by MOHURD, however, they are energy policies specific for the building sector, as national building energy policies, including architectural standards, building performance requirement, installing parameters, and codes of thermal and HVAC designs. They provide the rules of the calculation, and some of their index could indirectly and effectively affect the energy consumption in buildings. In this paper, major civil building standards of energy efficiency design and management during the modern development should been arranged and reviewed, classified as general-purpose standards, public building standards, residential building standards, and advanced building energy standards.

For effectively review major BEES, they can be classified into two types: first one is mandatory standards which are very comprehensive in building architecture, construction and system designs. This kind of BEES have design rules of construction, thermal design and engineering design of heating, ventilation, and air conditioning in buildings, and majority of their rules are mandatory for the construction process. Mandatory BEES can be further classified into more detailed types based on their target building types to public building standard and residential building standards. Secondly, in recent years, an even newer type of BEES has been issued. They do not have mandatory design rules, but massive new sustainable technologies, suggestions and encourage measures are introduced to building designers, with new concept such as green buildings. This is how the “advanced standards” is defined with diverse features of building engineering and technology.

3. Methodology

In this study, informative archival study is used for the collection of all the important national energy conservation policies implemented in building, energy and environment aspects during the China’s modern development dated from 1980 to 2019. Because of a large amount of data that required review, they are listed and reviewed in accordance with specific criteria. their purposes, policy innovation points, implemented years, and positions of the policy system, with discussion of their policy content. Secondly, the literature review was conducted on governmental database and research papers which were retrieved from governmental documents, yearbooks, websites, “Science Direct” and “Google Scholar”, with only peer-reviewed journal papers considered for the evaluation. The keywords used to initially filter the papers were “China”, “Energy”, “Policy”, “Building”, then “Renewable Energy”, “Sustainability”, “Low Carbon” and “Building Environmental Quality” were used to refine the research further. A set of 35 representative papers were identified, and their contents reviewed for the purposes of evaluating of the effectiveness of ECPB in China.

Furthermore, GPEBE and BEES including FYPs, national notices and actions, laws, and building energy efficient standards published in the last 40 years have been reviewed and discussed using content analysis method [29]. The next step of chronological review of policy content may explain how China has correspondingly presented their actions and solutions with milestone ECPB or international problems, such as protocols of climate change. Also, the introspection of these experience could be valuable for problem detections and future ECPB making when they are jointly analysed with historical events and follow-up effects.

Moreover, to support the discussion section, the selected academic research papers relating to ECPB development are also critically reviewed. The effectiveness of energy policy could not be accomplished by analysing governmental legislation alone. Considering the more realistic effectiveness of ECPB and massive policy content during the 50 years history, only statistics and policy content may not be reasonable proofs as they could be subject to bias. Therefore, it is also necessary to evaluate the underpinning research base upon which ECPB are based, so a series of research papers relating to China’s energy policy are critically reviewed and discussed to support the discussion. Accordingly, the research method can be summarised as below in **Figure 1**.

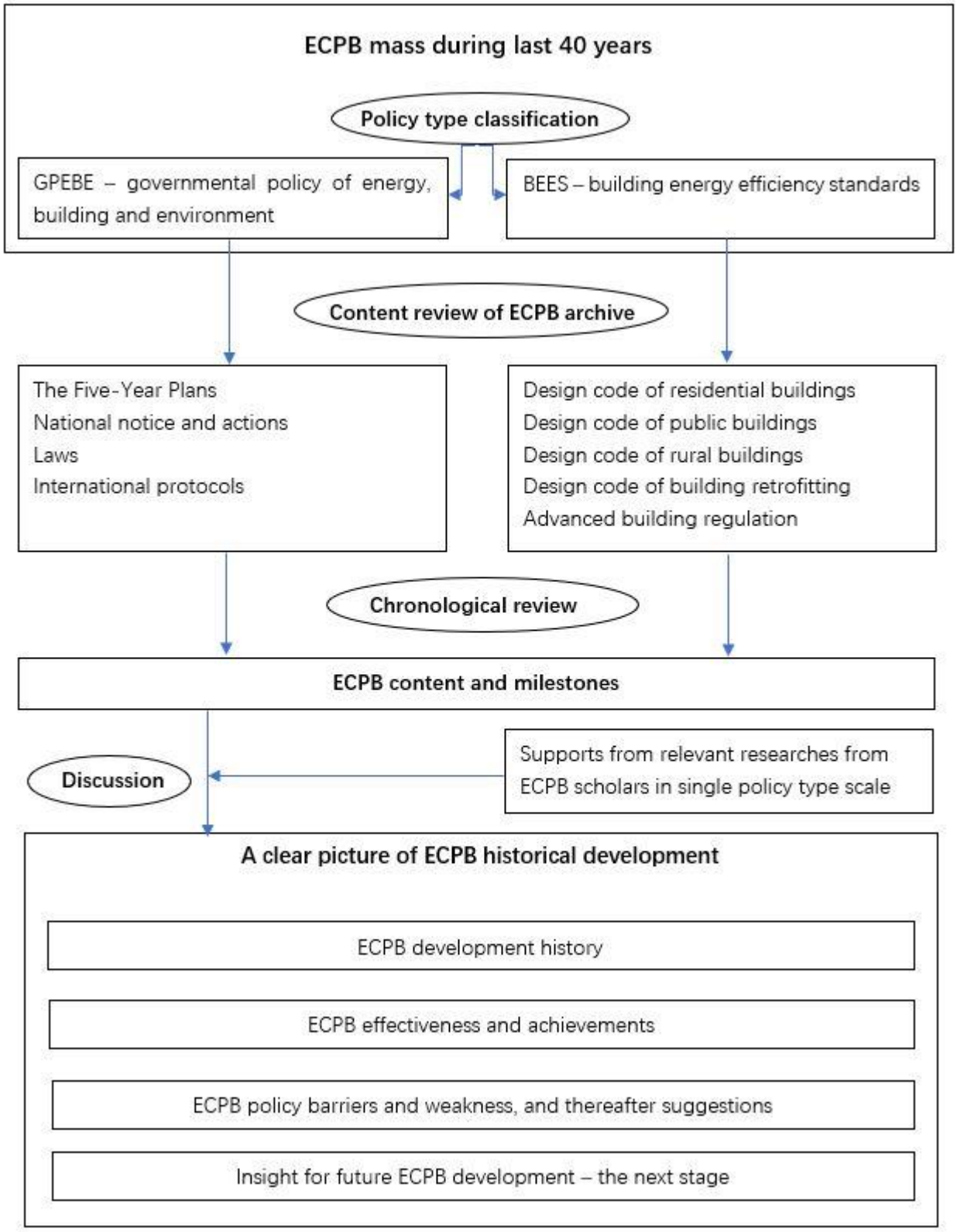

Figure 1 ECPB review research method of this study

The selected studies of GPEBE are initially classified based on the applied research methods, which are

listed in **Table 2**.

Table 2
Review of policy studies with different research methods

Evaluation Method	Policy studied	Focused aspects			Reference
		Energy	Building	Environment	
Statistical Analysis	Cleaner production	√	√	√	[24]
Statistical Analysis	NBS energy statistics	√	√		[30]
Statistical Review & Analysis	Energy performance contracting (EPC)	√	√		[31]
Statistical Review	Renewable energy	√	√	√	[32]
Statistical & Policy Review	Circular economy policy	√		√	[25]
Statistical & Policy Review	Renewable energy	√	√	√	[33]
Policy Review	10th Five-Year Plan Energy laws Building standards	√	√	√	[34]
Policy Review	11th Five-Year Plan	√	√		[35]
Policy Review	Renewable energy	√	√	√	[36]
Policy Review	11th Five-Year Plan National notice	√	√		[37]
Policy Review	Energy Efficient Buildings	√	√		[38]
Policy Review	1st-12th Five-Year Plans	√	√	√	[39]
Policy Review	12th Five-Year Plan National notice Energy laws Building standards	√	√		[40]
Policy Review & Comparison	National notice Energy laws Building standards	√	√	√	[41]
Policy Review & Comparison	Renewable energy Energy laws	√		√	[26]
Calculation Modelling	10th Five-Year Plan	√	√	√	[42]
Calculation Modelling	CO_2 reduction policy	√	√	√	[43]
Calculation Modelling & Mapping	Energy conservation policy	√	√		[44]
Questionnaire Survey	Clean development mechanism	√	√	√	[45]

Also a series of studies related with China BEES have been selected and analysed for the verification, as shown in **Table 3.**

Table 3
Review of building standard studies with different research methods

Evaluation Method	Research area	Target standard	Building Type	Climate Zone	Reference
Content Analysis & Statistic Review	Energy	GB 50178-93 GB 50189-2005	Public and residential	National	[46]
Content Analysis & Statistic Review	Energy	All	Public and residential	National	[18], [47], [48], [49]
Content Analysis & Statistic Review	Energy and design	GB 50189-2005 GB 50189-2015	Public	National	[50]
Content Analysis & Comparison	Energy	GB 50189-2005	Public	HSCW	[19]
Content Analysis & Comparison	Energy	GB/T51161-2016 GB 50189-2015	Public	National	[20]
Statistical Calculation	Energy	GB 50189-2005 JGJ 75-2003 JGJ 134-2010	Public and residential	SC, C, HSCW, HSWW	[51]

Table 3
Review of building standard studies with different research methods

Evaluation Method	Research area	Target standard	Building Type	Climate Zone	Reference
		JGJ 26-2010			
Statistical Calculation	Energy	GB/T51161-2016	Public and residential	National	[52]
Statistical Calculation	Indoor thermal environment	GB/T 50785-2012 GB 50736-2012	Public	National	[53, 54]
Case Study & Data Investigation	Energy	GB 50189-2015	Public - office	C	[55].
Case Study & Data Investigation	Energy	GB 50189-2015	Public - commercial	C, HSCW, HSWW	[56]
Case Study & Data Investigation	Energy	JGJ 26-2010 JGJ 134-2010 JGJ 75-2012	Residential	National	[49]
Case Study & Calculation Modelling	Energy	JGJ 75-2012	Residential	HSWW	[57]

4. Before 1995: Aggressive Development

Issued by National Development and Reform Commission (NDRC), the Five-Year Plans (FYPs) are the foundation for national policy. They are designed to set out the strategic direction of how the country will operate over the forthcoming five-year period. They hence provide invaluable sources of data in terms of the espoused top-down policy vis-a-vis energy, building and environment issues. There is however an under-utilized resource for researchers. The detailed review analysis is listed and can be found in **Appendix A**. It is found that before 1995, FYPs were the only national policy package which contains energy and building content [58].

However, during 1986 to 1995, the major task was to develop the economy. During this time, energy growth was the most important index with clear objectives [59]. This period could also be defined as ‘aggressive mode’ of national development of the 7^{th} and 8^{th} FYP focused attention only on economic growth. Increasing coal and oil consumption were hence considered as a means to an end without any consideration of their environmental impact. Environmental protection was only rarely discussed during this period [58]. The dominant modus operandi seemed to be ‘damage first and repair later’.

This shows that the governmental policy system in China has been constructed over the last 20 years and despite the progress made it continues to have many problems. A series of studies [35], [34], [26, 37-41] have reviewed and analysed the China GPEBE system at various stages of its development. Yao et al [34] and Huang et al. [41] criticize the slow speed at which local energy efficiency regulations have been issued. As a negative result, there are still massive amount of buildings exist today built during this period with very poor building performance parameters, which brings extreme pressure for building retrofit career.

5. 1995-2010: The Transition

5.1. The 9th to 11th Five-Year Plans

The period of 1992-1994 immediately prior to China joining UNFCCC is best described as 'transitionary' whereby the previous 'aggressive mode of development' was progressively modified with increased consideration of environmental impacts. Although the international protocols of climate changes remain heavily contested, they undoubtedly provided the impetus for the 'energy-saving and emission-reduction' programme initiated in the 1995 Five-Year Plan. From 1995, as the global background to energy growth changed, China started to consider issues of environmental pollution [60]. This was in part driven by events as such problems were becoming all too apparent. Issues were not limited to air pollution but also included the pollution of water resources and the legacy of toxic brownfield environments.

Simultaneously, the 1998 Asian Financial Crisis created significant shock to the national economic development. Economic development notably slowed down for a short period of time around 1998 [61]. After 2000, China's development strategy was adjusted to 'sustainable development' [62]. These years were characterised by a significant re-focusing of the policy agenda onto the twin themes of such as 'repair of damaged natural environments' and 'optimisation of the energy systems. Issues relating to 'environment and sustainability' were notably added into the FYPs, with a vast array of objectives set to reduce energy consumption, polluting emissions and the repair the nature environments. Arguably, there is another problem that the FYPs are still too general for detailed local use, as stated by Kong et al. [35] who have comprehensively reviewed all the important GPEBE issued during the 11th FYP period. It argues that ECPB is only routinely related to single buildings, rather than to different urban zones or even clusters of buildings within different climate zones.

5.2. National Notices and Actions

In 2005, the central government started to issue a new type of small-scale policy strategy which is enacted through national notices and governmental actions. In the name of the State Council (GOV) and the Standing Committee of the National People's Congress (NPC), this new type of policy aims at reinforcing the policies expressed in the FYPs. and to strengthens the applicability and supervision of FYP objectives. They notable provide more detailed guidelines in terms of how the policies should be implemented.

In the 11th FYP, the State Council started to create the detailed plans called 'national actions' relating to specific areas. It represents a very important step beyond what was offered in previous FYPs [63]. The increased level of detail content made it much easier for both relevant research institutes and private-sector enterprises to adjust their operational strategies accordingly. It is perhaps worth emphasizing that in China there is a much stronger expectation that operational managers should align themselves with top-down policy objectives than prevails in the West.

The national notices that relate to the three development aspects of energy, building and environment sectors from 1980s until today are listed in **Appendix B.**

5.3. The beginning of ECPB Laws

The first energy conservation law in China was notably established in late 1997, which is some 10 years after the first building energy standard. Driven by political forces and implemented through the imposition of penalties, laws are usually the strictest measures used in China to reinforce the implementation of policy [64, 65]. In this section, relevant energy and sustainability laws issued by the National People's Congress and its Standing Committee (NPC) are reviewed and analysed (see **Appendix C**). Hence legislation in support of energy and sustainability in China is relatively young comparison to Western countries. For example, the development of energy conservation legislation in the UK can be traced back for more than 40 years [66].

Given the relatedly recent introduction of energy-related legislation in China it is unsurprising that it is often less than perfect. Indeed, two critical shortcomings can be found in energy laws development – one is too general law clauses without related supervision and penalty measures. As in the first energy conservation law issued in 1997, only broad words such as 'cannot' and 'should not' have been presented for the actions against the energy conservation regulations [67]. However, it remains almost impossible to impose the stipulated penalties because of the lack of connectivity with civil law. Majority of paper from Kong et al. [35], Liu [65], Yao et al. [34], Zhang and Wang [37], Cai et al. [38], Huang et al. [41] mention this point that existing legislation is not strong enough to enforce the implementation of ECPB. Therefore, this problem has led to the energy legislation issued in the early years failing to fulfill its specified function of controlling energy waste and pollutions - such legislative failures are of course not limited to China, as evidenced by the ill-feted 'Green Deal' in the UK [68]. After almost ten years, the situation in China has been improved by the introduction of new legislation [69-71], and previous legislation has also been re-issued with added tax incentives and penalty measures [72].

5.4. The pioneer: BEES of residential buildings

Issued by MOHURD as detailed building engineering regulations, all BEES content during last 40 years have been reviewed, listed and discussed in **Appendix D**. Historically, industrial buildings were firstly applied with HVAC system standard, but the residential and hotel building type were the pioneers of energy conservation standards [73]. For the first time, JGJ 26 issued in 1987: Design standard for energy efficiency of residential buildings in severe cold and cold zones, is the milestone of China's BEES development with a 30% energy conservation rate was set compared with 1980s residential buildings. Improving the efficiency of boilers and system of heating stations was the biggest consideration in 1987 and 1995 (energy conservation rate improved to 50%) version of this standard [74].

For Southern China, JGJ 134: Design standard for energy efficiency of residential buildings in hot summer and cold winter zone. This BEES of the HSCW zone issued in 2001 focused more on cooling equipment efficiency, shading and natural ventilation. Meanwhile, their requirements of design parameters are more complicate with adaption of local people behavior habits and climate conditions. In the newest version of JGJ134, the minimum requirements of building envelope such as U-value and infiltration level have also been much improved [75].

Similarly, JGJ 75: Design Standard for Energy Efficiency of Residential Buildings in the Hot Summer and Warm Winter Zone, released in 2003, could be seen as a special version of JGJ134 with less content of

heating, but more approaches to solve problems of high temperature in summer [76], such as energy conservation techniques in indoor air-conditioning. Considering overheating issues, JGJ75 has very flexible rules in building envelope designs, but many unique mandatory requirements in shading, dehumidification and ventilation, which are reasonable based on the weather condition this standard apply [77], but same as others, this standard has not been upgraded for 6 years.

5.4. The beginning of mandatory rules: BEES of public buildings

Statistics showed that the number of public buildings in China was annually increased to 500 million m^2 in 2015, and that they consumed 7.5-15 times more energy than residential buildings [2], [78]. This may imply poor designs and operation methods in terms of energy efficiency, or it may imply that they end up being used in different ways to those envisaged. Therefore, the MOHURD has paid massive attention for energy efficiency career to public buildings [28], and this comprehensive building regulation could be considered as the most successful BEES package during the development of ECPB in China.

GB 50189: Design Standard for Energy Efficiency of Public Buildings, is the key and first mandatory BEES for China's public buildings. Although it was a very poor HVAC design code for tourist hotels in 1993 [73], this standard has successfully reduced 50% of energy consumption in new constructed public building sector [50] in 2005. Its 2nd edition in 2005 contained massive detailed index, information and approaches of calculation and application installation including building envelope in different climate conditions, lighting, HVAC equipment, occupancy behavior schedule, water system, and renewable energy applications [28]. This standard had become a reasonable template for further upgrades of residential building standards, had ended the old experience-relied design, and had made a good example which the other previous standards were too general. Furthermore, this standard had investigated the building information parameters of old buildings built around the 1980 years and made them as the baseline model for the further building retrofitting research.

6. After 2010: Sustainable Development of Energy and Buildings

6.1. The 12th and 13th Five-Year Plans

Thereafter, in the 11th FYP period of 2005 to 2010, the 'Energy-Saving and Emission-Reduction' strategy was formally confirmed by the State Council as the key theme of China's development [63]. The energy conservation objectives in the 11th FYP were far more ambitious than there were in the 10th FYP. Considerable emphasis was also placed on renewable energy. The expressed commitment to repairing and improving the damaged environments are even stronger in the most recent national policies, the 12th and 13th Five-Year Plans. In the building energy sector, the emphasis lies on improving the quality of the buildings in both urban and rural area. As a result, there was a boom in the number of policies, regulations and standard updates for new construction buildings and building retrofitting, which majority of them have higher objectives in energy-saving.

6.2. Improved energy and building laws6.3. Development of mandatory BEES

From 2010, as the energy conservation rate was further increased to 65%, there were more attentions paid into the building thermal performance index including building envelope U-value and air-infiltration. However, many mandatory has not been received any updates for years before 2010, and many design parameters are no more reasonable for today's energy conservation objectives. Later, the revision of JGJ 26, JGJ 134, JGJ 75 of mandatory residential building BEES all state for even more restrict rules, asks for a 15% to 30% more energy conservation rate compared to their old version [28],[75],[76]. Furthermore, these BEES started to clarify the building shape factor and window-to-wall ratio as mandatory index for building design, which proved the firm national development strategy of "energy saving and carbon reduction". Likely, in 2015, the GB50189 was updated to achieve 65% reduced energy consumption [2].

Moreover, in 2013, it was the first time that rural building and building retrofit have received attention from the BEES. GB/T 50824: Design Standard for Energy Efficiency of Rural Residential Buildings is the first national standard mentioned energy conservation in rural residential buildings [79]. This unique code is suitable for rural houses which have difficulties to reach the strict urban BEES due to complex social and economic reasons. Meanwhile, JGJ/T 129: Technical Specification for Energy Efficiency Retrofitting of Existing Residential Buildings is a first general standard for energy efficiency retrofitting, but many of its index and evaluation method are based on current residential new building standards. These standard have much less requirements both in amount and quality of energy conservation measures and design parameters than other urban new building BEES.

6.4. Integrated advanced BEES

The integrated BEES issued in the world are multifarious in measures, objectives and key aspects, and in China, it was firstly introduced in 2006 but rapidly improved till 2010 as JGJ/T 229-2010, to introduce the concept of green buildings. Likely as BREEAM and LEED standards, JGJ/T 229 and GB/T 50378: Assessment Standard for Green Building, is the China's green building assessment code that provides fundamental information of evaluation method, called 'China Green Building Label (CGBL)' in 2006. With a 16 years late than the UK's BREEAM from 1990, the CGBL was only a design-stage code with very general and simple content in 2006 when it was born. During the beginning of CGBL, majority of credits were given based on the GB 50983-2005 standard and old residential BEES, by simply asking 5% or 10% improved building parameter settings higher than these codes.

During 6 years, CGBL has been swiftly developed as 742 demonstrative building projects with 75 million m^2 building area [80]. In its 2014 version, there were massive content such as building operating assessment, lots of additional credits, and many improvements of evaluation methods added to make this CGBL tool became much more reasonable to be used. In 2019, the newest version of green building assessment code is issued, with a new credit index of "extra score" applied. This extra score allows building designs to use even more advanced measures of building energy conservation and sustainability beyond the governmental BEES, to reach a higher total green building score and get relevant financial and reputation supports [81]. Together with GB/T 50668-2011: Standard for Energy Efficient Building Assessment [82], they could be proof of related national financial support or energy discount measures.

More recently the Technical Guidelines of Passive, Ultra-low energy consumption, and Green buildings

(TGPUG) is an official technical guide presented in 2016 which started the new concept of using integrated techniques. This under-testing guideline focus on using integrated approach of combining passive design, high efficiency techniques and green building thinking to acquire the best goal of both the energy efficiency and sustainability. It uses the German Passive-House standard as the reference, as much increased building envelope U-value and air tightness compared with current national BEES, and uses green building assessment standards for land, water and energy saving purposes [83]. Later, GB/T 51350-2019, as called Technical Standard for Nearly-Zero Energy building (TSNZE) in design stage, is the newest BEES. This new standard raised the definition of "China's nearly-zero energy building" which requires about 60%-70% reduced energy consumption based on the current public and residential BEES [84].

7. Discussion

Supported by above sections of comprehensive review of ECPB, in this section, the detailed discussion is presented to analyse the ECPB milestones, historical development, policy achievements, policy barriers and suggestions.

7.1. A Clear Picture of ECPB Historical development

By summarizing the GPEBE and BEES reviewed in previous sections, the implementation numbers of ECPB development in China could be performed a figure shown below as **Figure 2**. It shows the implementation situation of ECPB in both numbers and time during the last four decades. From the figure, it is easily found that the frequency of new published and revised ECPB have a significant boundaries during the timeline between 10th to 11th FYP, and 11th to 12th FYP.

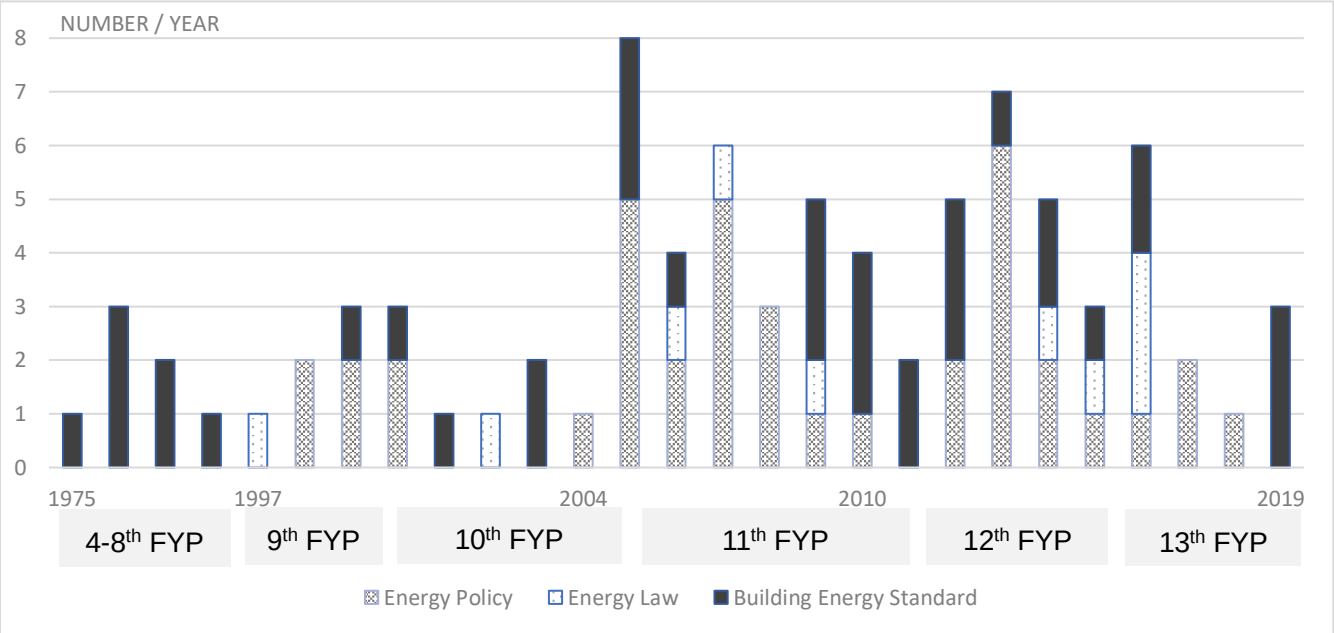

Figure 2 Number of energy policies, laws and standards issued during China's modern development from 1975 to 2018

To discover the milestone ECPB in the historical view, in 1987, the BEES for civil residential buildings were started to be divided as specific climate-respond standards in Severe Cold (SC) and Cold (C) climate zones; 2001 for Hot Summer and Cold Winter (HSCW) climate zone; and 2003 for Hot Summer and Warm Winter (HSWW) zone. So, for the first time of considering climate-respond design measures in building energy, the JGJ 134-2001 standard was a milestone of residential BEES during the China modern development.

For public buildings, however, the milestone arrived a later. In 2005, GB 50189, the first comprehensive BEES of public buildings finally started its function to control the energy consumption of buildings constructed without any official BEES. The standard ambitiously covered all five climate zones of China and almost every different type of public building. It was however nuanced enough to include energy conservation measures that were not evident in previous BEES, such as occupancy profile control and smart lighting control. The standard also included variety of climate-respond design measures. This method of localized thinking was further developed in first green building standard of China issued in 2006.

Much later, followed the new policy system of national notice and actions from 11th FYP, JGJ/T 229-2010: Code for Green Design of Civil Buildings was issued as a design code specifically for the new green buildings. This was a more comprehensive standard which introduced the distinction between 'passive techniques', and 'active techniques. It was also notable for establishing the concept of 'green design' in building thermal environments, HVAC and lighting system [85], which was further developed in the BEES of China passive housing. This latter code also emphasizes the importance of the building whole life cycle which was also reference of 2014 revision of GB/T 50378 green building standard.

Accordingly, the milestone ECPBs concluded could be summarised below in **Table 5**. The milestone ECPBs could be supported and discovered, hence a more detailed classification of development stages could be clearly defined.

Table 5
Milestones of ECPB development in China

Milestone events / policies	Year	Description
Energy conservation law	1997	First national energy conservation law
Asian Financial Crisis	1998	External factor that cause economic and energy shortage issues – changed the national energy development strategy to 'increasing generating annually' to 'reducing energy consumption and waste annually'
Kyoto Protocol	1998	First global protocol in climate change and GHG emission reduction
The 10th FYP	2000	First time mentioned "energy-saving and emission-reduction" as national development strategy
National notice and actions	2005	New government system to give quick order and feedback to the Five-Year Plans
GB 50189-2005	2005	First comprehensive energy conservation design code for public buildings
The 11th FYP	2006	First time presented 'sustainable development' as basic nation development strategy
Renewable energy law	2006	First official renewable energy law
JGJ/T 229-2010	2010	First comprehensive green building design code with engineering measures, rather than credit assessment tools
The 12th FYP	2011	Massive content in energy conservation of building, energy and environment

Based on the chronological review of ECPB content, history, relevant studies and milestone analysis from above sections, a clear grand picture of China ECPB historical development can be therefore generated , and it is finally classified as four stages during the studied timeline, presented as **Figure 3**.

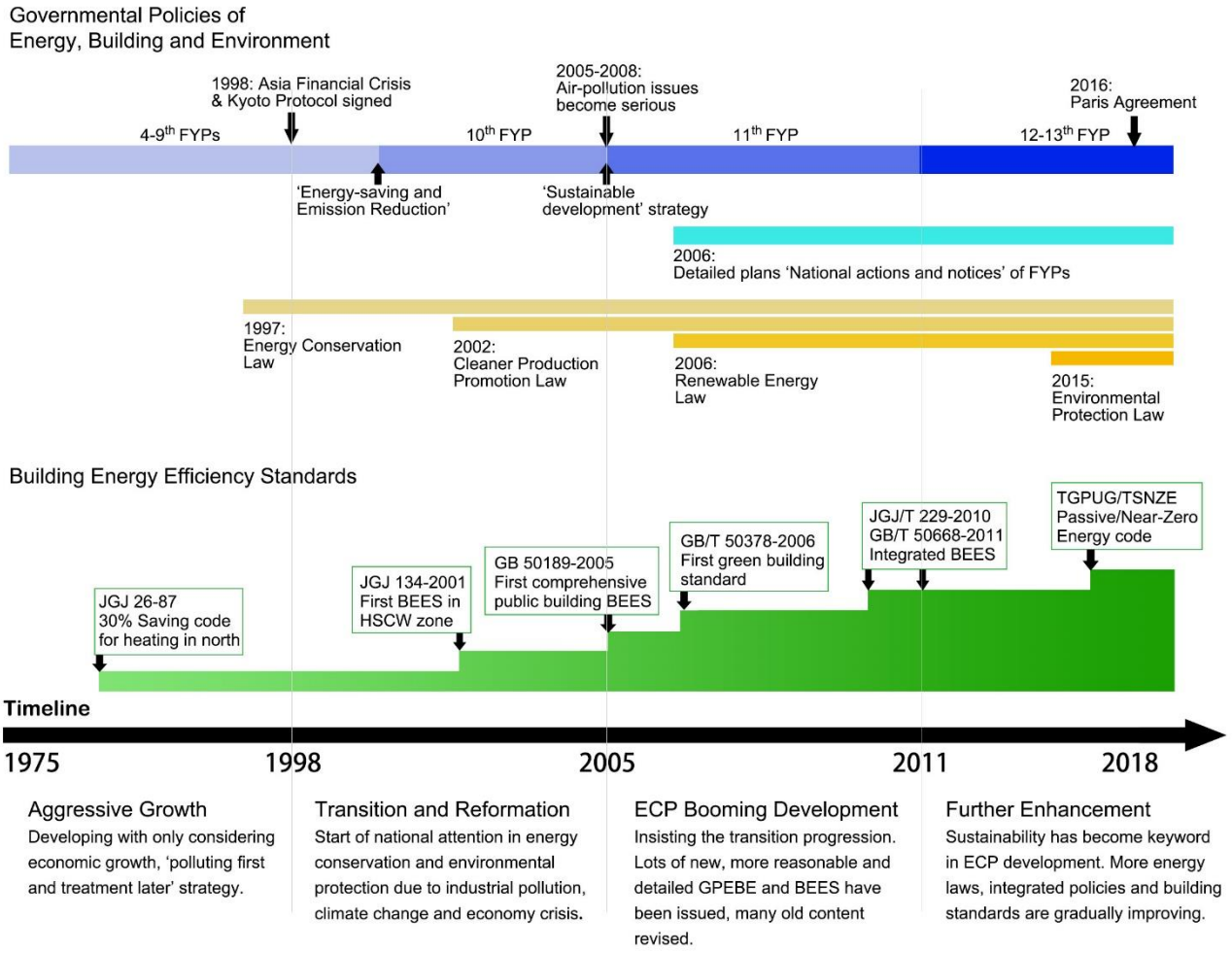

Figure 3 Chronology of ECPB development and ECPB milestones

1) 1975-1997: Aggressive growth

From the reviews of the ECPB objectives in the previous section, it could be found that before 1998, Chinese government paid major attention on developing energy industries, GDP, number of buildings, with an unsustainable strategy of 'polluting first, treatment later'. Although there were several encouragement policies of energy conservation and renewable energy in 7th to 9th FYPs, their objectives were too general. The first energy conservation law was issued by the NPC in 1997, was not very effective in aspect of controlling energy consumption. Also, its broad and general description of concepts and no designated governmental offices had resulted in an embarrassing position of powerless for many years [86]. Therefore, this aggressive strategy of development had planted the problematic seeds of energy and pollution, which had significantly affected the ECPB development in the later years.

2) 1998-2004: The transition and reformation

With the energy and pollution problems appeared and agreements signed on the Kyoto Protocol in 1998, it could be regarded the symbol of the transition of the changing of the development strategy to the 'sustainable mode'. The governmental policies of nation development had started to consider the energy-waste caused by economic and environmental reasons instead of blindly chasing higher objectives of industry achievements and GDP. This transition and reformation thinking brought valuable sustainable ideas and changes in energy and building policies, improvements of many old, general energy and environment laws, new editions of old building standards, and the 10th FYP with many new sustainable concepts had become the very foundation of future national development strategy reformation.

3) 2005-2010: Booming ECPB

Driven by the issues of national energy shortage, air-pollution and climate change, China insisted the reformation progress and has stepped into the stage of booming ECPB development during the 11th FYP period. The implementation of the first comprehensive national BEES [28] could be seen as the most important symbol which demonstrated the determination of China's strategy transition. More importantly, the improvements in relevant laws have received major updates, more details and closer connections with civil and criminal laws had made these laws become much more powerful to illegal activities and projects against the ECPB and BEES.

4) 2011 and later: Further enhancement

The ECPB development continues following the energy-conservation and pollution-reduction method after the transition. By reviewing the content in the 12th and 13th FYPs, it could be found that the 11th FYP had been used as an excellent template due to its more detailed, reasonable objectives and approaches in energy conservation and environment protection. Furthermore, with more completed establishment of legislative and execution system, the previous important energy laws had received major updates including energy conservation law, renewable energy law, and new environmental impact assessment laws. Also, new environmental protection tax law was implemented followed to further improve the legislation control. Accordingly, the enhanced ECPB had shown their essential roles in further improving stage of building energy conservation and sustainable development.

Besides, with the quantity of the ECPB issued is increasing, the quality of ECPB in China is also palpably improving after the transition of development mode. The FYPs now is having more detailed objectives and practical guidance; the national notices and actions are issuing more frequently to further provide directions to ECPB followers; the energy laws are revised much timelier, and the BEES are being added with more modern integrated energy conservation thinking and techniques. As a result, the progression of ECPB development is on an optimistic path.

7.2. Policy Achievements

Supported by the content reviews and analysis of the ECPB as well as relevant published researches presented in this study, the achievements of the GPEBE and BEES mechanism are analysed and could be summarized below as four key points.

1) Establishment of ECPB system

Policy system is effective but difficult to fully present its power to promote energy conservation due to

the complexities of the country's numerous populations, land area and types of climate, culture and social conditions. Thus, the policy system of large-scale countries needs to be efficient and powerful in authority and executing capacity.

By comprehensively reviewing almost all important ECPB issued during the period of modernisation, it has been found that China has chosen the 'top-down administrative method' for ECPB system and established a systemic policy system for energy conservation and environmental protection career. Also, revising antiquated GPEBE and BEES has become a common progression every year. Furthermore, the national notices and actions have proven as a great approach to optimise the familiar problem of 'too general content' in Five-Year Plans and 'too long period' in revising energy laws for its quick-responding effect.

2) Continuously insistent policies of energy conservation from the central government

From choronogical review, it is found that 'Energy-saving and emission-reduction' is continuously presented until today in every national energy policy after 2005. Historically, during the ECPB development, Chinese central government has presented a very strong statement of 'transition and reforming' to change the previous 'aggressive mode of energy development' into 'energy conservation and sustainable mode' in 10^{th} and 11^{th} FYPs. As great determination made effects, recently, every single clause of ECPB has mentioned this national strategy, which are frequently reminding all energy industries and construction enterprises to bear in mind about energy conservation.

3) Improved and more detailed progression

Based on the content reviewed of BEES development timeline, the building design index, energy conservation measures, and building energy conservation applications are improving and becoming more comprehensive. It is evidenced that BEES have received gradually improvements by more detailed and scientific revisions, as well as more considerations to introduce new thinking of comfort and sustainability. For example, the thermal requirement of building envelope set in BEES have been progressed gradually in each revision and updates, such as more considerations were added in [2] including number of floors, sub-climate conditions under the five base climate zones, and shading approaches in hot summer zones.

4) Effectiveness in building energy efficiency and sustainability

Most importantly, the effectiveness of energy conservation promoted by ECPB is also proven appreciable from other researchers. Peng and Liu [24], Huo et al. [30] used top-down calculation method based on the national statistics, estimated an increase from 17.7% to 20.3% in terms of energy efficiency in the building sector due to GPEBE implementation. Jiao and Boons [25] used both statistical calculation and a case study method to translate the circular economy policies and showed their results in energy conservation. Furthermore, Chai and Zhang [42] provided different scenarios of ECPB transitions in 10^{th} FYP and made projections of their effectiveness till 2050, showed a 25% CO_2 reduction in 2020 and over 50% rate of renewable energy usage could be reached in 2050. Yuan and Zuo [39], Tan et al. [43] present a review of GPEBE clauses and statistics, they acquired the reduction and 2050 projection data of carbon emission effectiveness, while [43] simulated and admired the progression of current ECPB which can reach the objective of 50% CO_2 reduction in 2046, 4 years before the 2050's target.

Li and Shui [18], Huo et al. [47], CABEE [49], Zhang et al. [52] also used top-down statistical

calculation method to evaluate the ECPB effectiveness. CABEE [49] argues that the application of BEES has resulted in significant reductions in energy usage. The claim is that the period 2007- 2014 saw a 10% annual energy reduction rate in urban public buildings, 5% in urban residential buildings, and a 53% total energy reduction rate in district heating system used in north China area. Yu et al. [51] also gave a long term CO_2 projection view from 2005 to 2095, stated a 13%-22% national CO_2 reduction caused by BEES' effort.

Scholars also used case study methods to provide examples of BEES effectiveness in the investigated buildings. Wei et al. [55] developed a city-level BEES benchmarking system, investigating 88 office buildings in one city and evaluating their energy efficiency. Yet their results indicate a rate that BEES requirements were only partly applied in majority real projects. Also papers provided by Huo et al., Guo et al., and Chen et al. [56, 57, 87] take several cities as case studies, investigated and analysed their urban statistics to get the success of energy conservation effects from BEES.

Accordingly, the effectiveness of the 'top-down administration' method of ECPB contributed largely to the achievement of country's carbon emission reduction target, however, there are still many problems appeared within them, which are discussed in the next section.

7.3. Barriers and Suggestions for the Next Stage

During the fast growth of ECPB development, there are also many limitations and shortcomings discovered from the review and analysis of ECPB content and studies. After reviewing the ECPB development of their content, the main problems found are pointed out as below in six parts. Accordingly, the fifth stage – 'the entrie improvement' stage could be expected as the next stage of China's ECPB development in the future, by applying suggested solution measures to overcome all aboved disscsued policy barriers.

1) Frequency of policy update

As the most intuitive issue, frequency of policy update is a big concern for China ECPB's future career. There is a figure which can show the updating frequency situation of China ECPB so far as below in **Figure 4**.

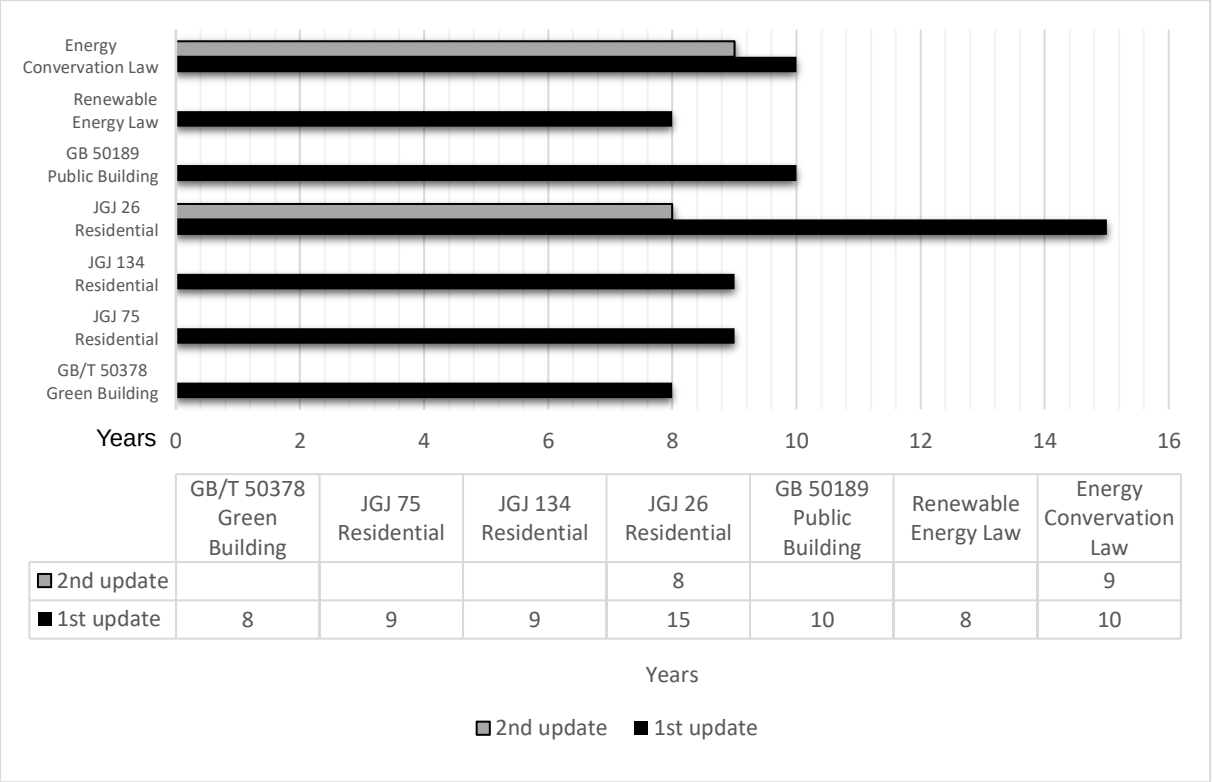

Figure 4 Years taken for the ECPB update (number 0 to 16 on the figure)

From the figure we can see that the gap of updating the ECPB was very long, as at least 8 years for a single law or BEES to receive an amendment. For example, the JGJ 26 about district heating system was updated in 2010 after it was firstly issued in 1995. Furthermore, the JGJ 26 and JGJ 134 have not been updated for 8 years since the last issue, with many building parameters have become antiquated. Therefore, it is urgent to have a new appropriate BEES to suit the current situation of higher energy efficient demand in residential buildings and heating system.

Compared with other developed countries such as the UK's BEES, there is approximately one version of amendment issued each year. Although it might not be necessary to update the ECPB too frequently, many studies reviewed have still pointed out that the current ECPB update are not timely which seems to be cumbersome in contrast with rapidly created and improved energy efficiency technologies. Accordingly, accelerating the effectiveness of ECPB system means there will be more appropriation for relevant manpower of governmental workers and energy researchers, and this is helpful to increase the ECPB supervision strength simultaneously, by developing the method of ECPB administrations. Referencing the UK's practice of using energy performance label in each single building of the country [66], it could referenced if this be an appropriate supervision approach, similar as the energy statement mechanism mentioned by many studies [49, 87].

Meanwhile, more researches with ECPB administration analysis would be valuable - rather than general statement as 'lack of supervision' in many research papers, there is also only little researches with statistical analysis similar as study [48] that provided exact data of ECPB supervision situation. On this point, studies with statistical analysis of ECPB implementation circumstance would be very helpful for policymakers to find their working focus and direction of endeavor. For example, it was proved by studies that China's urban BEES for new buildings have successfully reached the 100%

implementation rate in 2012 from only 54% in 2006 [48] with intensive political controls in construction management. Similarly, policy-makers could apply the similar approaches to increase supervision strength of new testing, retrofitting, and voluntary BEES.

2) Supervision of policy implementation

As a top-down administrative control, public policies can be very powerful and effective, but also could be the useless blank slate if no governmental forces of regulators to execute the content, rules, and implementation rate from relevant administrative institutions [88]. Furthermore, guaranteed policy implementation effectiveness is fundamental for majority of building energy researches - it is easily found that majority scholars calculate the policy effectiveness with a “default hypothesis” which buildings are built completely following current ECPB, and most of building energy simulation studies have designed their building characterizes from policy content of BEES.

However, it is not rare to find that the policy was implemented but not fully applied to the reality [88]. Guo et al. [48] is valuable which provide statistical supported data of ECPB supervision situations. It was suggested that critical problem prior to 2012 related to the extent to which BEES was fully applied. This study showed that there was only 21% compliance rate in the construction stage in 2005, later it was gradually increased as 54% in 2006, 71% in 2007, and 82% to 100% from 2008 to 2012. Liu et al. [32] analysed the demonstration projects for renewable energy applications, stating that the incentive award mechanism for both energy conservation and renewable energy institutes is the best approach to quicken their development. Zhang et al. [31] surveyed buildings under the use of Energy Performance Contracting (EPC). It focuses critical attention on the problems of current EPC policies such as low specificity, not enough further investment, and no proper building maintenance because of insufficient policy supervision.

As it is a global challenge to effectively and fully apply the designed policy to reality [5], it is important to further improve the strength of ECPB supervision and management, in the way such as improve the frequency of building energy efficiency inspection and reporting, or increase the power of controlling laws, monitoring, and examinations. The reviews have shown that the early ECPB including the FYPs, energy laws, and building standards had problems with too general content, which made them difficult to be followed and supervised. With the development of ECPB in recent years, this issue has been gradually solved by revising old ECPB. However, as the ECPB now become stricter for the energy and building industries, the supervision of ECPB still needs enough political attention to force their implementation with sound financial support or penalty measures.

3) Local-respond policy

Considering unique local strength and conditions in aspects of local climate, social and energy resource condition is essential to achieve higher energy conservation effectiveness of ECPB in a large country scale. The current ECPB are still not comprehensive enough with individual local situations. Regional variation in ECPB studies from previous studies, Zhou et al. [45] suggests establishing a mechanism which incentivizes clean development and creating regional building energy indicators to monitor local policy administration. Zheng et al. [44] further mapped the efficiency of ECPB measures based on data envelopment analysis with energy companies, highlighting the importance of diverse climate conditions of regions that affected the ECPB effectiveness, which are helpful for the development of localized responses.

Besides, there are many studies have discussed the advanced techniques of energy sustainability

which may further enhance the BEES effects based on unique local conditions. Li et al. [53], and Li et al. [54] evaluated the BEES with indoor thermal comfort characteristics, estimating the adaptive occupancy behavior of 'free-running buildings' could be considered in BEES which may become a path to further increased the energy conservation effects. Later, this statement is supported by Yao et al. [4] which applied passive design measures to extend the non-heating and cooling period to achieve a 18%-24% energy conservation effect in HSCW climate zones.

In new integrated BEES issued, more local designs, including climate-responding design in building envelope, shading and HVAC equipment, and behavior-responding design in lighting controls are added into the design rules. It can be inferred that the ECPB system is taking more local condition responding thinking into account. Additionally, combined with considerations of local conditions, specifying the climate conditions and resource advantages with meticulous and detailed climate zones can be helpful for local governments to use.

4) Renewable energy progression

Another possible improvement is the progress of renewable energy development. In FYPs, the objectives of renewable energy share were gradually increased from 1.8% in 2006 to 11.4% in 2011 and to 15% in 2016, but it was still a 'predicted' target rather than other tough mandatory goals, without enough detailed ECPB content to help to achieve them [65]. Therefore, there should be more powerful policies in renewable energy and sustainability, including centralized policy and incentive financial support for related market.

Comparatively, the Renewable Energy Directive (RED) in the European Union and the Renewables Obligation (RO) and the United Kingdom have both significantly improved the renewable energy development by mandatorily set certificate requirement rules to energy suppliers to increase the share of electricity generated by renewable energy resources. From the reports, RED was proven that the European Union has increased it average renewable energy share from 8.5% in 2004 [89] to 17% in 2016 [90], and a revised objective has been set as 27% target for 2030. The RO in the UK has also shown its effectiveness of percentage of supply from 3% in 2002 to 15.4% in 2016, and a further high target in 2037 [91]. Similar as EPC method, studying this legislative-certificate approach would be useful for ECPB-makers to consider about how to improve the sustainability for China's future.

5) Building energy efficiency retrofit

Because of energy conservation development in residential buildings started in 1995 for only heating in SC and C zones, it brought a circumstance that a vast number of existing buildings were built with poor thermal performance materials and now still remain low energy efficiency. Moreover, energy retrofitting objectives are on less important stage in the FYPs, either the BEES of retrofitting [78] have least content and less mandatory design rules than new building BEES. As a result, there is a remote path for China to claim the energy-saving and emission reduction potential in building energy retrofitting. A more specific, integrated policy with engineering, economic and social considerations should be well-developed.

6) Rural buildings

Similar as building retrofitting, the problems of ECPB implementation in rural buildings are also in a critical stage, and even more serious and complicated. Policies reviewed show that since majority of rural buildings are usually constructed and operating without any consideration of BEES before 2013

when the first rural BEES released [79], the amount of energy-saving potential could be numerous. With the development of rural economy in recent years [49], the trend is that people start to seek a better indoor thermal comfort in rural area. Therefore, the country should present a comprehensive ECPB approach for the new and existing rural buildings. Yet the challenges are also tough - there are more unique considerations for rural buildings.

8. Conclusions

This study used chronological review method to review, retrospect and analyse the historical development, policy content, and policy effectiveness of China's Eneryg Conservation Policy of Buildings (ECPB). The clear grand picture and detailed development stages are acquired; the milestone policy and achievements of ECPB historical development are discussed and evidenced; and their policy barriers and suggestions are discovered. The major conclusions can be summarized as follows.

Firstly, massive policy content reviewed in this chronological review study can novelty provide extremely informative and coherent data for relevant studies of building energy in China. The grand picture of ECPB historical development is acquired with four detailed stages identified and categrised, and identification of the milestones during the ECPB development have showed their historical importance to launch new stages of ECPB development. Since the policy upgrades prove that the ECPB system has significantly different and improved stages and transitions during the timeline development, it is also evidenced that future ECPB designs should be closely connected to the timely demand of national objectives of energy, building and environment.

Secondly, the structure and positive effects of top-down administrative policy measures are evidenced from the disscsuion. It is found that GPEBE system is constructed by components of the Five-Year Plan, National Notice, Laws to set national objectives in energy, environment and economy aspects. These objectives are followed and achieved by detailed BEES system underpinned by individual standards for different climatic zones and building types. Accordingly, this thorough system is the key to effectively implement relevant regulations to construction sites in China. Consequently, magnificent achievements have been obtained in building energy conservation and carbon emissions reduction.

More importantly, exsiting policy barriers and problems which are uniquely identified in this paper should draw policymakers' attentions based on the evidence discussed. Consequent suggestions are proposed and solutions are disscsued for a better future of China's ECPB development. Exposed issues discovered in this study could become guidance to support policymakers for their future ECPB designs. By overcoming current policy barriers, the next stage of ECPB development in the future can be inferred as the insight of this research - the fifth stage of 'entire improvementt' after the current "further enhancement stage" in the China future ECPB development. Combined with the review and disscsuion, it is suggested that national GPEBE such as the next 14th Five-Year Plans to have more detailed objectives in renewable energy, sustainability, building retrofit, and rural buildings. For future BEES, balanced frequency of content updates with better, stricter and more appropriate local design parameters are adviced, with stronger supervison authority applied to building engineering site to achieve higher implementation rate and better result of energy conservation.

Finally, this study also novelty demonstrate a systemic approach of policy review in an extremely long

timeline and country-scale. Extensively, this method can be applicable to other countries to evaluate their policy of building energy conservation, and discover their own historical development, achievements and problems.

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Appendix A

Review of the 7th – 13th Five-Year Plans

Summary of the policy objective information from the Five-Year Plans in development of energy, building and environment

FYP	Year	Energy	Building	Environment
7th	1986-1990	➢ 3.4% annual increased of energy generation ➢ 17.6% increased coal production, 20% oil, 16.6% natural gas ➢ Reduce oil-burning to 18% from 40% ➢ 23.5% total investment for energy facilities ➢ 11.6% energy conservation rate ➢ Reduce energy consumption as 100 million tons of SCE	➢ 40% increased output value ➢ Spread usage of standard glazing ➢ Develop higher energy-efficient wood/coal boilers ➢ 650 million m^2 more urban residential buildings ➢ 50 million m^2 more central heating area	➢ Encourage biogas and hydropower facilities in rural area
8th	1991-1995	➢ 32% increased electricity generation ➢ 12.8 increased coal production, 5% oil ➢ Reduce energy consumption as 100 million tons of SCE ➢ 2.2% annual energy saving rate for five years	➢ Improve and retrofit urban plan and basic facilities ➢ More construction projects of public buildings	➢ Develop facilities of waste and pollution treatment
9th	1996-2000	➢ 7% increased electricity generation ➢ Increase the using of natural gas, further reduce oil-burning ➢ Start to design and implement energy conservation regulations	➢ 500 billion CNY increased output value ➢ 1 billion m^2 more urban residential buildings ➢ Start to limit poor thermal performance brick buildings ➢ Start to retrofit poor thermal designed old buildings	➢ Encourage using of all kinds of renewable energy sources ➢ Increased industrial water waste treatment rate to 83%, gas waste 86% ➢ 50% Recycle rate of solid waste ➢ 27% urban water waste treatment rate, domestic garbage 50%
10th	2001-2005	➢ Optimize the structure of energy generation and consumption ➢ Improve the efficiency of exploitation and utilisation coal, oil and gas mines and products ➢ Further increase the usage and generation of primary electricity instead of fossil fuel burning	➢ Optimize the economy structure of urban and rural area ➢ Increased urbanisation rate ➢ Increased development of urban public buildings and facilities ➢ Average residential area per person increased to 22 m^2	➢ Environment and sustainability became one major section in the plan ➢ 10% reduced overall pollution ➢ Issue water, grassland, ocean and forest protection policies ➢ 45% urban water waste treatment rate, up from 27% ➢ 20% reduced sulfur dioxide emission ➢ Forest cover rate to 18.2%
11th	2006-2010	➢ 9.82% increased annual primary energy generation ➢ 4% increased annual energy consumption ➢ Reduce energy consumption as 560 million tons of SCE ➢ 4.4 % annual energy conservation rate	➢ 150 million m^2 houses get energy efficient retrofit ➢ Increase all energy efficiency rate of facilities and equipment in buildings ➢ Increase central heating supply rate to 40% from 30% ➢ Develop new materials for better	➢ 10% reduced overall pollution ➢ 320 million tons of reduced carbon dioxide emission ➢ 8.4 million tons reduced sulfur dioxide emission ➢ Reduce the number of coal mines ➢ 5000 m^2 solar-heating hot water

Summary of the policy objective information from the Five-Year Plans in development of energy, building and environment

FYP	Year	Energy	Building	Environment
		➢ 1.8%, 0.1%, 0.8%, 0.4% increased usage of natural gas, nuclear, hydraulic and other renewable energy	thermal and energy efficiency building design	facilities ➢ 156 billion CNY appropriation for environmental protection (200% more than 10th FYP)
12th	2011-2015	➢ 'Energy' section was converted as 'Energy and sustainability' section ➢ Energy generation and consumption increase rate are no longer objectives ➢ 11.4% non-fossil fuel resources usage ➢ 16% energy conservation rate in five years ➢ Issue energy-label system and consummate the energy conservation regulations ➢ 4% replacement rate of renewable energy to total energy	➢ 990 million m^2 houses get energy efficient retrofit ➢ 100% rate of building standards apply to urban new buildings ➢ 36 million more sets of affordable urban housing ➢ Issue new building design standards and codes ➢ Develop public building and facilities in rural area ➢ Strongly encourage the new energy saving techniques in building design ➢ Massive appropriation in building and HVAC energy-efficient research ➢ Stably increase the urbanisation	➢ 17% reduced carbon dioxide emission ➢ 8% reduced sulfur dioxide emission and chemical oxygen demand ➢ 10% reduced ammonia oxide and nitrogen oxide emission ➢ Forest cover rate to 21.66% ➢ Control and solve the urban air-pollution issues ➢ 85% urban water waste treatment rate, domestic garbage 80% ➢ Strengthen the environmental supervision and management
13th	2016-2020	➢ 15% non-fossil fuel resources usage ➢ 15% energy conservation rate in five years ➢ Limit coal mine development ➢ Develop primary electricity and renewable energy ➢ Coal consumption share reduced to 62% ➢ 6% replacement rate of renewable energy to total energy	➢ 500 m^2 residential and 100 million m^2 public buildings get energy efficient retrofit each year ➢ 50% increased green buildings in urban new buildings ➢ Accelerate and fasten the urbanisation process ➢ Change the urban development style to improve urban environmental and living quality ➢ Develop towns and villages ➢ Develop and improve the public buildings and facilities in rural area ➢ Massive appropriation in building and HVAC energy-efficient research	➢ 18% reduced carbon dioxide emission ➢ 15% reduced sulfur dioxide and nitrogen oxide emission ➢ 10% reduced chemical oxygen demand and ammonia oxide emission ➢ 23% water conservation rate ➢ Forest cover rate to 23.04% ➢ Control and solve the water and air-pollution issues ➢ 20% reduced land using conservation rate ➢ Develop the repair projects of eco-systems

***The conservation rate is defined as the related consumption saving per 10,000 CNY (Chinese Yuan) of GDP**

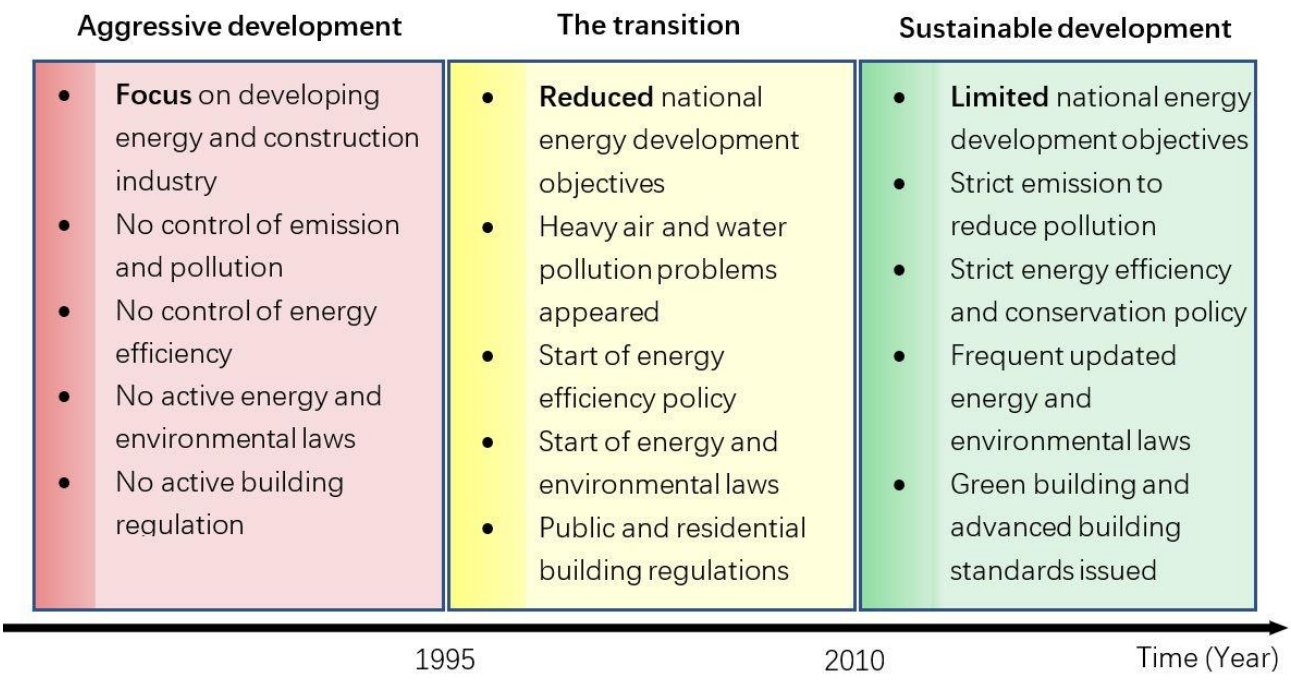

Figure Appendix A: Summary of three stages of FYPs of ECPB content

Appendix B

Tables of National Notices and Actions

National Notices

Policy name	Year	Authority
Notice on issue of energy conservation law	1998	NPC
Notice on issue of regulation on environmental protection management of construction project	1998	GOV
Notice on issue of the outline for national ecological environmental protection	2000	GOV
Notice of developing abstemious society – recent key projects	2005	GOV
Notice on further promoting wall material innovation and popularizing energy-saving buildings	2005	GOV
Notice on further Strengthening the supervision of building energy efficiency standards	2005	GOV
Notice on organizing special inspection of building energy efficiency	2005	GOV
Notice on investigation work related to building energy conservation	2005	GOV
Notice on decision of the State Council on strengthening energy conservation	2006	GOV
Notice on issue of energy development plan in 11th Five-Year Plan	2007	NDRC
Notice on issue of the comprehensive scheme for energy-conservation and emission-reduction	2007	GOV
Notice on issue of China's national plan to tackle climate change	2007	GOV
Notice on issue of renewable energy development plan in 11th Five-Year Plan	2008	NDRC
Notice on issue of energy-conservation and emission-reduction plan in 2009	2009	GOV
Notice on issue of energy-conservation and emission-reduction plan in 12th Five-Year Plan	2012	GOV
Notice on issue of greenhouse gas emission reduction plan in 12th Five-Year Plan	2012	GOV
Notice of green building action plan	2013	MOHURD
Notice on issue of energy development plan in 12th Five-Year Plan	2013	GOV
Notice on issue of circular economy development strategy and short-term action plan	2013	GOV
Notice on issue of the energy-conservation and emission-reduction plan (2014-2015)	2014	GOV
Notice on issue of the energy development strategy action plan (2014-2020)	2014	GOV
Notice on issue of greenhouse gas emission reduction plan in 13th Five-Year Plan	2016	GOV
Notice on issue of energy-conservation and emission-reduction plan in 13th Five-Year Plan	2017	GOV

National Actions

Policy name	Year	Authority
Measures for the management of China's energy saving products certification	1999	NPC
Energy saving management method for key energy consuming units	1999	NPC
Regulations for energy conservation management in civil buildings	2000	MOHRUD
Guidance on developing energy-saving and land-saving housing and public buildings	2004	MOHURD
Regulations for energy conservation management in civil buildings (2nd edition)	2006	MOHURD
Guidance on integrated utilisation of resources in 11th Five-Year Plan	2007	NDRC
Implementation scheme of the energy-conservation and emission-reduction plan	2007	MOHURD
Regulation for energy conservation in civil buildings	2008	GOV
Regulation for energy conservation in public governmental buildings and facilities	2008	GOV
Opinions on accelerating the implementation of energy performance contracting (EPC)	2010	GOV
Opinions on accelerating the development of energy saving and environmental protection	2013	GOV
Guidance on strengthen the urban public facilities construction	2013	GOV
Green building and green eco-cities progress plan in 12th Five-Year Plan	2013	MOHURD
Guidance on standardisation process of energy conservation works	2015	GOV
Building energy conservation and green building progress plan in 13th Five-Year Plan	2017	MOHURD
Energy saving management method for key energy consuming units (2nd edition)	2018	NPC

Appendix C

Laws of Energy and Environment in China

Laws of Energy and Environment

Code of law	Year	Main and Added Content	Ref.
Energy Conservation Law	1997	➢ Legislative authority and responsibility statements for the national energy conservation, pollution emission control and repair of environment. ➢ Restrictions of energy waste, low energy-efficient industry activities ➢ Management and supervision methods of mandatory energy-saving rules ➢ Tax, price and financial appropriation policies for energy conservation action	[67]
	2007	➢ Broadened the aspects which are controlled by the law, added energy conservation in building, transportation and public facilities	
	2016	➢ Increased the control strength to mandatory energy conservation rules and standards in building design and energy projects	
Cleaner Production Promotion Law	2002	➢ Improvement of design measure, usage of clean energy, clean production techniques and equipment, management of producing process ➢ Methods of reducing energy consumption and pollution emission from the source and by increasing the efficiency utilisation	[92]
Renewable Energy Law	2006	➢ Encouragement of the development of renewable energy ➢ Protection for the renewable energy business	[93]
	2014	➢ Added the methods of electricity grid combination for the electricity generated by renewable energy	
Circular Economy Promotion Law	2009	➢ Legislative authority for the sustainable development of industry and economy growth ➢ Comparison of developed countries' cases and discovery of the new circular economy promotion strategy suitable for China	[69]
Environmental Protection Law	2015	➢ Legislative authority and responsibility statements for the national environmental protection career ➢ Increases the level of environmental protection to the basic state policy ➢ Much more detail (1st edition was in 1973, but too general and inefficient)	[72]
Environmental Impact Assessment Law	2016	➢ Provides guideline of environmental and sustainable analysis, projection and evaluation approach for planning and construction project ➢ Standardisation of environmental monitoring and management and provide scientific data statistics for relevant environmental protection policies	[70]
Environmental Protection Tax Law	2016	➢ Punitive taxation for high-level energy consumption and emission industry ➢ Discount taxation for energy-saving, clean and renewable energy industry	[71]

Appendix D

Building Energy Standards in China

Development of issued national building standards. Divided by the milestone BEESs (highlighted).

Code	Standard Focus	Year	Coved Building Type	Climate Zone*
TJ 19-75	HVAC design	1975	Industrial	National
GBJ 19-87	HVAC design	1987	All	National
JGJ 26-87	Energy conservation design for heating	1987	Residential	SC, C
JGJ 37-87	Architectural design	1987	Civil	National
GB 50176-93	Thermal design code	1993	Civil	National
GB 50189-93	Energy conservation design	1993	Hotel	National
JGJ 26-95	Energy conservation design for heating	1995	Residential	SC, C
GB 50096-1999	Architectural design	1999	Residential	National
JGJ/T 129-2000	Energy conservation retrofitting	2000	Residential	National
JGJ 134-2001	Energy conservation design	2001	Residential	HSCW
GB 50019-2003	HVAC design	2003	All	National
JGJ 75-2003	Energy conservation design	2003	Residential	HSWW
GB 50189-2005	**Energy conservation design (2nd edition)**	**2005**	**Public**	**National**
GB 50352-2005	Architectural design	2005	Civil	National
GB 50368-2005	Architectural design	2005	Residential	National
GB/T 50378-2006	Green building assessment	2006	Civil	National
JGJ/T 132-2009	Energy efficiency test	2009	Residential	National
JGJ 176-2009	Energy conservation retrofitting	2009	Public	National
JGJT 177-2009	Energy efficiency test	2009	Public	National
JGJ 26-2010	Energy conservation design	2010	Residential	SC, C
JGJ 134-2010	Energy conservation design	2010	Residential	HSCW
JGJ/T 229-2010	**Green building design**	**2010**	**Civil**	**National**
GB 50096-2011	Architectural design	2011	Residential	National
GB/T 50668-2011	Energy conservation building assessment	2011	Civil	National
GB 50736-2012	HVAC design	2012	Civil	National
JGJ 75-2012	Energy conservation design	2012	Residential	HSWW
JGJ/T 129-2012	Energy conservation retrofitting (2nd edition)	2012	Residential	National
GB/T 50824-2013	Energy conservation design	2013	Rural residential	National
GB/T 50378-2014	Green building assessment (2nd edition)	2014	Civil	National
CSUS/GBC 05-2014	Green building testing	2014	Civil	National
GB 50189-2015	Energy conservation design (3nd edition)	2015	Public	National
GB 50176-2016	Thermal design code	2016	Civil	National
GB/T 51161-2016	Energy consumption control	2016	Civil	National

*Standards in grey color are specific building energy conservation standards

*SC for Severe Cold climate zone, C for Cold, HSCW for Hot Summer and Cold winter, HSWW for Hot Summer and Warm Winter