ENERGY EFFICIENCY CHINA 2018

CCEEE

ENERGY · EFFICIENCY · ECONOMY

2018 ENERGY EFFICIENCY CHINA

This report expertly fills a longstanding void in comprehensive and up-to-date English-language reporting on China's innovative energy efficiency policies, programs and results. The report will surely be useful for professionals engaged with China or wishing to understand perhaps the strongest national energy efficiency drive in the world. The addition of chapters on investment and service market development, complementing overview and sector chapters, is especially noteworthy. The report abundantly uses time-series and up-to-date statistics to show trends and latest developments clearly. For those wishing to learn even more, the lists of references and 2017 policy documents are very valuable.

I hope very much that this reporting will continue on an annual basis, with new, up-to-date information every year. This would unquestionably be an excellent global GHG reduction investment, supporting global knowledge exchange and cross-flow of information on emerging innovative energy-efficiency policies and programs and their results.

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former Energy Sector Leader for East Asia and Pacific, The World Bank

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Foreword

Energy efficiency has been a "hidden fuel" since the 1970s. Nowadays, energy efficiency is identified as the "first fuel" and many governments and the international community have made efforts to fully utilize this resource. In addition to the well-known benefits of reducing energy consumption and cutting greenhouse gas emissions, energy efficiency improvements are bringing significant environmental, social, and economic benefits, including improving air quality, enhancing energy security, reducing energy expenditures, and promoting economic prosperity. Energy efficiency has been adopted by industry, buildings, transportation and citizens with most of the benefits being realized as "avoided" energy consumption. The nature of energy efficiency determines that its important role is relatively undetectable. Although energy efficiency is receiving more and more attention both globally and in China, the degree of emphasis does not yet match its significance.

China is a fast-growing emerging economy and the world's largest player in energy consumption and greenhouse gas emissions. China faces the challenge of balancing economic and social development versus addressing the challenges of energy and climate change. Energy efficiency improvement can provide the solution - consuming less energy to produce the same or more output. Energy savings and low emissions are not in conflict with economic development. Energy efficiency improvement is also an inevitable choice for China's development - the pursuit of high quality, high efficiency growth is a goal that China has been seeking. China enacted the *Energy Conservation Law* in 1998. Since then, China's energy efficiency work has made significant progress domestically as well as contributions to global energy efficiency improvement.

With the objectives of comprehensively digesting information about China's energy efficiency improvement work in recent years, further promoting the concept of "energy efficiency as the first fuel", and introducing China's relevant policies and programs to people outside China to benefit their work in addressing energy and climate challenges, the China Council for an Energy Efficient Economy (CCEEE) convened a group of young energy efficiency experts in China to jointly develop the *Energy Efficiency China 2018* report. The report consists of five main sections that review and summarize China's energy efficiency work in 2017 and before. The report's opening section describes progression of global energy and climate actions and China's role in the global energy efficiency effort. The following sections introduce specific work in China, which include an overview of energy efficiency in China, energy efficiency in key sectors, and energy efficiency investment & financing and market in China. The report ends with major conclusions and recommendations.

The *Energy Efficiency China 2018* report is the first volume of CCEEE's *Energy Efficiency China* series, prepared in both Chinese and English. In the future, we hope to continue to compile this series of reports, to track and report the progress of China's energy efficiency improvement in the global response to energy and climate change challenges, and to witness China becoming a participant, contributor and leader in global energy efficiency improvement!

桑晶

SANG Jing

Executive Director of the China Council for an Energy Efficient Economy (CCEEE)

December 18, 2018 in Beijing, China

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Energy Efficiency as the “First Fuel”

Humans consume energy to meet their living needs, i.e. food consumption, product manufacturing and building services like cooling and lighting; yet the current level of global energy consumption is causing a global energy crisis and climate change that the world is striving to address. Improving energy efficiency[1] is a key solution to both challenges of energy and climate change. At the same service level, energy efficiency could reduce consumption of fossil fuel energy while reducing greenhouse gas (GHG) emissions. The recognition of the significance of energy efficiency evolved in three phases (Figure 1). People were not aware of its importance until the first world energy crisis in 1973, and countries started seeking solutions for achieving energy security and sustainable development. In 1976, Amory Lovins first prompted the world “to use less energy and produce more output”, which provoked broad discussion [2]. Since then, energy efficiency has won more attention as a “hidden fuel” and has had great impacts on the energy policies of many countries.

Research has shown that implementation of effective energy efficiency policies could reduce end-use energy consumption by 20% in industry, buildings, transportation, and lighting and equipment in the Organization for Economic Cooperation and Development (OECD) countries in 2030 [3]. Moreover, the International Energy Agency (IEA) found that in its first 11 member countries, the energy savings from energy efficiency investment between 1974 and 2010 outweighs the energy supply from any single fuel. Later, the IEA made a formal statement that energy efficiency is not only a “hidden fuel” but also the “first fuel” [4]. Energy efficiency is now on its way to being widely accepted as the “first fuel”, thus becoming a global focal point in energy policymaking and climate actions because of its abundant “reserves” and cost-effectiveness[2].

1. Energy efficiency is the ratio of output (service, product or performance) to energy input [1]; sometimes people also use energy consumption per unit of output (known as energy intensity) to describe energy efficiency: if something is low in energy intensity, it is high in energy efficiency.
2. Compared with supply-side energy sources, energy efficiency as a fuel could reduce energy demand at lower costs and at the same time benefit power systems, end users and society [5].

Figure 1 The evolvement of recognition of energy efficiency

With the signing of the *Paris Agreement* in 2015, the world has reached consensus to "keep a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels (referred to as "2 Degree Goal" thereafter) and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius" (referred to as "1.5 Degree Goal") [6][7]. However, judging from the emissions reduction[3] progress up to date, even the opportunities to realize the 2 Degree Goal are fading. Therefore, countries need to find effective emissions reduction strategies as urgently as possible to accelerate the pace. Improving energy efficiency in industrial facilities, buildings, and the transportation sector is among the most cost-effective emissions reduction methods and the greatest contributor by far to emissions reduction; according to IEA projections, energy efficiency could contribute as much as 48% in the midterm (by 2030) to achieving the 2 degree Celsius goal [8]. It is obvious that energy efficiency has great potential for GHG emissions reduction in all sectors and can bring significant economic and development gains. It is a critical pathway in both energy and climate terms to improve energy efficiency by strengthening energy policies, generating energy savings, and making good use of energy efficiency as the "first fuel".

Progression of Global Energy and Climate Actions

The *Paris Agreement* requires all Parties to submit "ambitious" (i.e. best effort) nationally determined contributions (NDCs) to respond to the threat of global climate change. The Parties should report their progress regarding NDCs every five years starting from 2023, and any update should be under the principle of "progression", meaning all Parties can only strengthen their efforts and will try their best to reduce emissions as things move forward [7]. Most of the Parties specify energy efficiency as a key strategy for cutting emissions in their NDCs. As the IEA noted, however, even if all NDCs to date are achieved, it is still not enough to realize the 2 degree Celsius goal [8]. Therefore, to better cope with the globally shared challenge posed by climate change, the Parties should not only make every effort in achieving their NDCs, but also boost efforts in further tightening their emissions reduction targets and strengthening international cooperation for climate actions.

3. In this report, emissions reduction refers to the reduction of GHG (carbon dioxide and others) emissions unless otherwise stated.

In tackling climate change and energy issues, many countries have followed best practices from developed countries and regions, especially the United States (U.S.) and Europe. As the world's second largest energy consumer and GHG emitter after China, the U.S. consumed 18% of the world's total primary energy and generated 15% of global GHG emissions in 2015 [9][10]. The U.S. has been a key provider of clean technologies and green funding around the world in fighting against climate change. The current administration, however, announced on August 4, 2017 its plan to withdraw from the *Paris Agreement*.[4] Based on current energy consumption and emissions trends of the U.S., the British Broadcasting Corporation (BBC) estimates that the country's withdrawal from the *Paris Agreement* would add an extra 0.3 degree Celsius to the average global temperature in 2100, assuming all the other Parties implement their NDCs as planned [12]. There is no doubt that the lack of support for the *Paris Agreement* of the current U.S. administration represents a loss of a critical driving force for the international community in addressing climate change.

As another major player in energy efficiency improvement, the European Union (EU) provides several good examples. The EU set an energy efficiency target of saving 20% of its energy use by 2020 compared with the reference scenario[5] in its *2012 Energy Efficiency Directive* [13]. In 2016, the European Commission considered adopting a 30% energy savings target for 2030[6] with corresponding measures in its updated *Energy Efficiency Directive*. The EU Parliament and the Council of the European Union reached an agreement on June 14, 2018 to set a 32.5% energy savings target for 2030 with a clause for upward revision by 2023. To achieve its rigorous and continuously improving energy savings targets, the EU has taken several actions with a focus on comprehensive planning, energy markets, sectoral policies,and public awareness in sectors where there is great energy savings potential, altogether achieving impressive results [1]. The EU has established itself as a role model for all other countries working to save energy.

But energy and climate change issues are complex, with various interests from different stakeholders; countries are also in different phases of development and therefore have different needs. Developing countries need suitable strategies for addressing energy and climate change challenges. On the one hand, experience from developed

4. Note that the U.S. has not yet filed the paperwork required to withdraw from the *Paris Agreement*. According to the *Paris Agreement*, any country that intends to withdraw from the Agreement cannot officially claim such intention until November 4, 2019, and the withdrawal procedure takes one year [11].

5. According to the *2012 Energy Efficiency Directive* of the EU, projections made in 2007 showed a primary energy consumption in 2020 of 1,842 million tons of oil equivalent (Mtoe). A 20% reduction means 1474 Mtoe in 2020 [13]. The reference scenario refers to the scenario where projections are made under business-as-usual situations, i.e. the "natural" or "blank" continuation of the current situation without implementation of any additional energy efficiency measures.

6. All EU energy saving targets refer to energy use reduction compared with the reference scenario of the same year, unless otherwise stated.

countries may not be able to meet the needs of developing countries, which often face the challenge of achieving a balance between economic growth and mitigating climate change; on the other hand, best practices from developed countries could be further adapted for use in developing countries.

As the world's largest developing country and GHG emitter, China has long been exploring development pathways that work best for meeting local conditions while taking international accountability for emissions reduction. The IEA's *Energy Efficiency 2017* shows that China made remarkable progress in energy efficiency in 2016, with the best performance overall in the coverage and strength of energy efficiency policy and the greatest increase in energy efficiency investment in the world [14]. As a means of strengthening domestic effort and international collaboration in addressing climate change, the Chinese government announced two organizational changes in 2018 - establishing the Ministry of Ecology and Environment, which includes the Department of Climate Change that previously belonged to the National Development and Reform Commission (NDRC), and forming the International Development Cooperation Agency [15]. These shifts aim at capturing the co-benefits of cutting GHG emissions and improving domestic environmental quality while strengthening international collaboration in all aspects, including energy and climate change.

These actions, from a policy and organizational perspective, have created an environment conducive to addressing climate change. Over the years, China has successfully adapted international experiences to local conditions to establish new practices that work in China. One example in adapting international experiences is the successful Energy Conservation Actions in Top-1,000 Enterprises program (and its successor, the Energy Conservation and Low Carbon Actions in Top-10,000 Enterprises program) that resulted in combined energy savings of over 400 million tons of coal equivalent (tce) between 2006 and 2015.[7] Another example is the energy performance contracting (EPC) model, which was introduced to China in 1998 via the World Bank/Global Environment Facility (GEF) China Energy Conservation Promotion Project. After 20 years' development, China is now the world's largest EPC market [16]. Experience from China could diversify and broaden international experiences where other countries are seeking their own energy and climate pathways. As the largest emitter yet an active player in cutting emissions, China not only makes direct contributions to global efforts in addressing climate change through a wide range of actions including energy efficiency measures, but also strives to support other countries, including the Belt and Road Initiative countries, in achieving their 2030 Sustainable Development Goals.

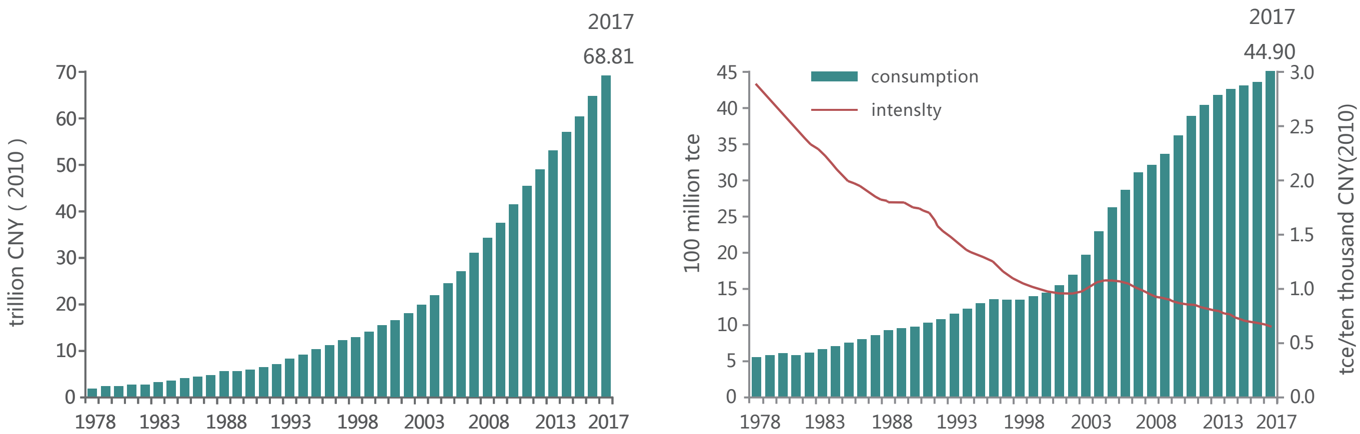
7. Data from http://www.efchina.org/About-Us-zh/Case-Studies-zh/case-2014112606-zh.

China’s Role in the Global Energy Efficiency Effort

In the mid-to-late 1990s, China's national economy began to take off through comprehensive development (Figure 2a), but the resulting energy and environment problems have become increasingly serious; energy consumption, environmental pollution, and GHG emissions have all increased significantly (Figure 2b). In response to the energy, climate change, and environmental issues brought about by rapid economic development, China has introduced a number of corresponding policies and initiatives, and has taken actions to promote effective policy implementation.

In November 1997, the National People's Congress (NPC) of China passed the *Energy Conservation Law*, which was officially implemented in 1998. The Law was under development since 1989[8] and is China's first basic law on energy conservation. The Law aims to promote energy conservation in the whole society, improve energy efficiency and economic efficiency, ensure economic and social development, and meet the needs of the people's livelihoods. Its implementation indicates that China has established an important position for energy conservation from the legal and institutional perspective [17]. With the implementation of the *Energy Conservation Law*, a series of energy conservation policies and regulations related to industry, building, and transportation as well as end-use products and public awareness have been introduced one after another, which has promoted overall improvement of energy efficiency. Between 1998 and 2002, China’s energy consumption intensity, defined as energy consumption per unit of GDP, fell by an average of 2.5% (Figure 2b).

8. The formulation of the *Energy Conservation Law* began in 1982; in 1984, the State Economic Commission and the State Planning Commission proposed the outline of the *Energy Conservation Law*; in 1989, the State Planning Commission continued to investigate, and in 1990, the outline was prepared, and the draft of the *Energy Conservation Law* was completed on the basis of the outline. Over the next three years, the draft was revised multiple times, and the draft of the *Energy Conservation Law* was submitted for review. Later, on July 14, 1993, the State Planning Commission and the State Economic and Trade Commission sent the draft to the State Council for review.



a. GDP in China (1978-2017)

Source: *China Statistical Yearbook*

b. Energy Consumption and Intensity in China (1978-2017)

Source: *China Energy Statistical Yearbook*

Figure 2 GDP, Energy Consumption, and Energy Intensity in China (1978-2017)

At the same time, due to the rapid development of China's economy, especially high energy-consuming industries, total energy use and intensity of China's energy consumption increased from 2002 to 2005, and the growth rate of total energy consumption in 2003 and 2004 was much greater than that of GDP. China became the country with the largest total carbon emissions and highest total energy consumption in the world in 2006 and 2009, respectively [18][19]. Faced with these challenges, the Chinese government has given unprecedented attention to energy conservation and emissions reduction.

Since 2006, China has begun to use reduction of energy intensity as a binding indicator[9] and implemented a strict annual assessment. In 2007, the National People's Congress of China revised the *Energy Conservation Law*. Since 2007, the Chinese government has successively issued a series of comprehensive policies targeting energy efficiency, including the *Comprehensive Work Plan on Energy Conservation and Emissions Reduction in the 12th Five-Year Plan*[10] *Period,* the *12th Five-Year Plan on Energy Conservation and Emissions Reduction,* the *Strategic Action Plan on Energy Development Strategies (2014-2020),* etc. In 2016, the National People's Congress further amended the *Energy Conservation Law*. The Chinese government issued the *Comprehensive Work Plan on Energy Conservation and Emissions Reduction in the 13th*

9. A binding indicator is a requirement to perform better than the anticipated baseline; it is placed by the national government on its departments as well as on provincial and local governments for public services. It is meant to improve government accountability, and the relevant government agencies/departments are responsible for its realization (source: http://www.gov.cn/ztzl/jnjp/content_673529.htm).

10. The Five-Year Plan is a mechanism by which the Chinese government does its national development plans in five-year intervals. It started in 1953 (shortly after the founding of the People's Republic of China in 1949) with the 1st FYP period being 1953 to 1957. From 1963 to 1965, there was no FYP as the country was experiencing an economic readjustment time. Currently, China is in its 13th FYP period (2016-2020).

Five-Year Plan Period, and in the same year China began to impose the "double controls" policy to reduce both energy intensity and total energy consumption. These policies and measures show that energy conservation and emissions reduction are among the highest priorities of the Chinese government's agenda. On the basis of the above policies and plans, the Chinese government has been vigorously promoting energy auditing and energy efficiency benchmarking in key energy-consuming enterprises[11] and successively carrying out the Energy Conservation Actions in Top-1,000 Enterprises[12] and Energy Conservation and Low Carbon Actions in Top-10,000 Enterprises[13] programs. On average, China's energy consumption intensity fell by 4.3% annually from 2006 to 2017 (Figure 2b).

Over the past two decades, China's energy efficiency work has achieved remarkable results: in 2016, energy savings generated by energy efficiency improvement reached 1.1 trillion USD, ranking first in the world and accounting for half of the global "energy productivity bonus" [14]. It is worth emphasizing that China's per capita GDP and per capita energy consumption levels still have a large gap with developed countries. Even under such circumstances, China has put forward the targets of controlling total energy consumption and intensity, which demonstrates China's commitment to sustainability.

The concept of "ecological civilization" that conforms to nature, respects nature, and protects nature is now the guiding ideology for actively addressing climate change and energy challenges in China. It is also seen as fundamental to solving problems in a series of human development processes, including climate change and energy issues. In 2012, the 18th National Congress of the Communist Party of China made a strategic decision to "strengthen the construction of ecological civilization", also laying out the long-term blueprint for China's ecological civilization construction.[14] In 2015, China's State Council issued the *Opinions on Accelerating the Construction of Ecological Civilization*.[15] In October of the same year, "enhancing the construction of ecological civilization" was first written into the national Five-Year Plan (FYP).[16] In 2017, Chinese President XI Jinping mentioned tackling climate change in the report of the 19th National Congress of the Communist Party of

11. Key energy-consuming enterprises refer to: 1) enterprises that have annual energy consumption of above 10,000 tce, or 2) enterprises designated by specific government departments with annual energy consumption below 10,000 tce but above 5,000 tce (source: *Energy Conservation Law*).
12. The program aimed to save energy in 1,008 enterprises whose annual energy consumption in 2004 was over 180,000 tce. The enterprises were selected by the central government from nine key energy-consuming industries (source: http://www.ndrc.gov.cn/rdzt/jsjyxsh/200604/t20060413_66114.html).
13. The program aims to save energy and cut emissions in 16,078 key energy-consuming enterprises (source: http://www.gov.cn/banshi/2012-05/23/content_2143552.htm).
14. Retrieved from http://www.gov.cn/jrzg/2012-11/08/content_2260442.htm.
15. Retrieved from http://www.gov.cn/xinwen/2015-05/05/content_2857363.htm.
16. Retrieved from http://www.china.com.cn/lianghui/news/2016-03/17/content_38053101_2.htm.

China, and pointed out that China has taken an active part in international cooperation on climate change in the past five years and has become an important player, contributor, and leader in the construction of global ecological civilization.[17] A Constitutional Amendment, passed in March 2018, emphasizes the responsibility of the State Council for "leading and managing economic work, urban and rural construction, and ecological civilization construction".[18] Prioritizing ecological civilization has created an environment conducive to energy efficiency improvement in China. As shown in the following efforts, China has been active on the international stage of low carbon development and energy efficiency improvement:

- In September 2016, the Group of Twenty (hereinafter referred to as "G20") countries jointly approved the *G20 Energy Efficiency Leading Programme* (EELP) at the G20 Summit in Hangzhou, China. The G20 EELP is the first document that China led under the G20 framework, and represents China's willingness to contribute to global energy efficiency improvement. The paper points out that energy conservation and energy efficiency improvement are some of the best ways to rationally use energy resources and that strengthening cooperation in energy efficiency can promote economic development and productivity growth [20].
- In May 2017, the Chinese government issued the *Guiding Opinions on Promoting the Construction of the Green Belt and Road* to encourage green development across Belt and Road countries. The Guiding Opinions aim to share China's experience and best practices in dealing with challenges of energy and climate change with Belt and Road countries, thus helping more countries pursue low carbon development [21].
- In June 2017, the 8th Clean Energy Ministerial (CEM 8) was held in Beijing, China. This meeting reflected global attention to the development and utilization of clean energy technologies and the international community's desire for developing clean and efficient energy systems. As the host of CEM 8, the Chinese government expressed strong willingness to devote itself to sustainable development.
- In November 2017, the China Pavilion of the United Nations (UN) Climate Change Conference in Bonn (COP 23) featured a side event on the "Contribution of China's Energy Efficiency Improvements to Global Climate Change Mitigation". This is the first time that the China Pavilion organized a side event specifically on energy efficiency. At the event, the Chinese delegation had meaningful discussions with energy efficiency professionals from all over the world, demonstrating China's strong interest in actively participating in global energy efficiency dialogues and collaborations.

17. Retrieved from http://cpc.people.com.cn/n1/2017/1028/c64094-29613660.html.
18. Retrieved from http://www.xinhuanet.com/politics/2018lh/2018-03/11/c_1122521235.htm.

- In May 2018, at the 9th Clean Energy Ministerial (CEM 9) in Denmark, the Chinese delegation elaborated on Chinese President XI Jinping's New Development Concepts, which includes the “green development concept”.[19] The Chinese delegation also summarized the China action plan on high quality development based on the New Development Concepts, drawing broad attention from countries participating in CEM 9. China also introduced specific actions in the fields of innovation and application of clean energy technology research and development, and proposed the establishment of a regional energy interconnection initiative under the CEM mechanism. In addition, the number of countries that have expressed interest in joining the Electric Vehicle Initiative proposed by China and several other countries continued to increase, and a number of countries approached China to explore opportunities for cooperation related to energy efficiency. Thus, China is having an increasing impact within the CEM mechanism [22].

At home, China has been carrying out campaigns to raise public awareness about energy efficiency in all aspects. China’s Energy Conservation Week (ECW) has been held for 27 years, which includes the National Low Carbon Day that was first held during the ECW in 2013 [23]. China have launched a series of activities during the Energy Conservation Week and on the National Low Carbon Day to promote energy efficient and low carbon lifestyles to save energy and reduce emissions in citizens’ daily life.

China is an emerging economy and the world's largest energy user and GHG emitter. The stance and actions that China takes not only have an impact on the long-term development of China itself, but also have a profound effect on international society. China, through great effort, is showing the world that it is striving to shoulder its international responsibilities and make serious efforts in moving itself towards an energy efficient economy. There are still problems to be solved, however, China's efforts are demonstrating to the world that there is a bright future for energy efficiency in China.

19. At the 5th Plenary Session of the 18th Central Committee of the Chinese Communist Party in October 2015, Chinese President XI Jinping first prompted the New Development Concepts of innovation, coordination, green development, opening and sharing. For more details, see http://cpc.people.com.cn/n/2015/1111/c64094-27801025.html.

1. Overview of Energy Efficiency in China

China's energy efficiency work started almost simultaneously with the Reform and Opening Up period in the late 1970s, and has gone through 40 years. Since the mid-to-late 1990s, with the rapid development of the national economy and the growing prominence of energy and environmental issues, China's energy efficiency work has become more and more important. This section provides an overview of China's energy efficiency work. It takes the implementation of the 1998 *Energy Conservation Law* as the starting point, summarizes key developments in China's energy efficiency policies over the past 20 years, and lays out the current situation.

Energy Conservation Management System in the Government

In accordance with the provisions of the *Energy Conservation Law*, China's energy conservation-related work is supervised and managed by relevant authorities within the government (Box 1). In China's energy efficiency governance structure, the division of labor is clear and each authority has its own function (Figure 3).

Box 1　Government Organizational Setup for Energy Conservation in China

Government

Responsible for leading energy conservation work at its level, including deploying, coordinating, supervising, monitoring, and promoting energy conservation. The government refers to the State Council at the national level, and refers to local governments at the provincial, city and prefecture level (provinces, autonomous regions, municipalities directly under the central government, cities, regions, leagues, prefectures, and prefecture-level cities and districts).

Government energy conservation department

Responsible for the supervision and management of energy conservation at its level. The national energy conservation department/authority is the National Development and Reform Commission (NDRC), and in a local government the energy conservation department/authority is either the local Development and Reform Commissions, or the local Economic and Information Commission/Office/Bureau.

- **Energy conservation supervisory agency**: special local government agency responsible for energy saving-related law enforcement supervision at the prefecture level and above; the energy conservation supervision agency is generally more effective at provincial and city levels than at the prefecture level.

Relevant government departments Responsible for energy conservation supervision and management within their respective functions and duties at their respective levels, and follow the guidance of the energy conservation departments of the same level. At the national level, the relevant departments are departments that have responsibility for energy conservation other than the NDRC, and may be divided into departments/authorities that focus on specific sectors or deal with specific areas (similar at the local level).

- **Sector-specific departments/authorities** – departments/authorities with sectoral management responsibilities for energy use (such as the Ministry of Industry and Information Technology for industry, the Ministry of Housing and Urban-Rural Development for buildings, the Ministry of Transport for transportation, and the National Government Offices Administration for public sector).
- **Departments/Authorities that deal with specific areas** – special departments/authorities that do not fully supervise overall energy conservation work of energy users, and only perform special duties, such as the financial department managing financial incentives, inspection departments inspecting retrofit projects and spending, enforcement supervisory departments overseeing enforcement of energy savings standards, measurement, and market supervision of energy savings products, etc.

Note within one specific province/city/prefecture, take Beijing for example; under the Beijing Municipal Government, there is only one energy conservation department (i.e. Beijing Municipal Commission of Development and Reform), but there are multiple relevant departments with different functions.

Source: *Energy Conservation Law*

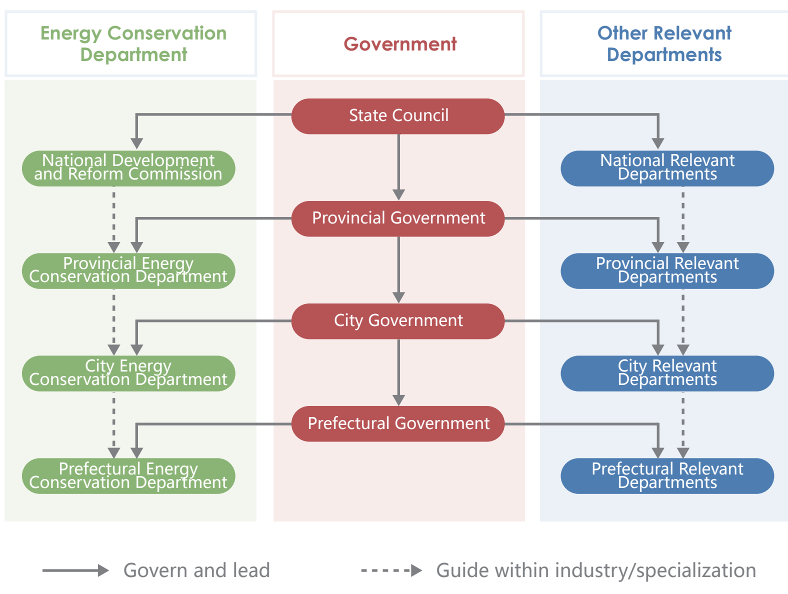


Figure 3 Government Management System for Energy Conservation in China

Source: *Energy Conservation Law*

Departments of the higher-level government do not govern lower-level governments (e.g. the NDRC or the National Ministry of Finance does not govern the Beijing Municipal Government), and thus cannot directly assign work to the latter, except in cases when the State Council (i.e. the national government) authorizes higher-level departments to do so. For example, for annual evaluation of progress towards achieving energy savings targets, the NDRC was given authority by the State Council to carry out provincial assessments, and in this case provincial governments need to report to the NDRC in terms of their energy savings targets achievement.

Energy Efficiency Policies' Important Guiding Role

Directed by the basic state policy of China to conserve resources as well as the *Energy Conservation Law*, the Chinese government has put forth a series of comprehensive energy efficiency policies over the past two decades (Figure 4), and implemented them through the energy conservation management system discussed in the preceding section.

1997	*Energy Conservation Law of China* (implemented in 1998)
2001	*10^{th} FYP on Energy Conservation and Comprehensive Utilization of Resources*
2004	*Outline of Mid- to Long-Term Energy Development Plan (2004-2020)* *Special Plan on Mid- to Long-Term Energy Conservation*
2005	*State Council's Notice of Improving Near-Term Key Efforts to Build Conservation-Minded Society*
2006	*State Council's Decision on Reinforcing Energy Conservation*
2007	*Comprehensive Work Plan on Energy Conservation and Emissions Reduction* *National Plan of China on Climate Change Mitigation* *Energy Conservation Law of China, Amendments in 2007* (implemented in 2008)
2011	*Comprehensive Work Plan on Energy Conservation and Emissions Reduction in the 12th FYP Period*
2012	*12^{th} FYP on Energy Conservation and Emissions Reduction*
2014	*Strategic Action Plan on Energy Development (2014-2020)*
2015	*Opinions on Accelerating the Construction of Ecological Civilization* *Overall Plan on the Institutional Reform of Ecological Civilization*
2016	*Energy Conservation Law of China, Amendments in 2016* (implemented in 2016) *Comprehensive Work Plan on Energy Conservation and Emissions Reduction in the 13^{th} FYP Period*

Figure 4 Comprehensive Policies for Energy Conservation and Emissions Reduction in China (1997-2016)

Source: compiled from notices and announcements at http://www.gov.cn/zhengce/index.htm

Energy efficiency policies in China used to focus on energy conservation rather than emissions reduction. Starting in 2006, when China became the world's largest GHG emitter [18], China placed a growing emphasis on the synergistic effects of energy conservation and emissions reduction, and began to integrate these two goals in the policy agenda. The priority level for these two topics was further escalated since 2009, when China became the world's largest energy user [19]. After 2010, Chinese policies on energy efficiency, climate change mitigation, and ecological civilization have become more intensive, increasingly large-scale, and focused on the long term. Under the guidance of these policies, the Chinese government has introduced policies for specific sectors, industries, and markets to promote the overall improvement of energy efficiency.

Significant Energy Intensity Reduction and Slow Energy Consumption Growth

With the implementation of the *Energy Conservation Law* and a series of energy savings actions across the country, China's energy intensity continued to decline from 1998 to 2002, with an average annual decline of 2.5%, from 1.05 tce/10,000 2010CNY of GDP in 1998 to 0.95 tce/10,000 2010CNY of GDP in 2002. In 2003 and 2004 when China's economy grew very rapidly, the energy intensity increased, and the growth rate of total energy consumption (16.8%) even exceeded the growth rate of GDP (10.1%). Since then, China has given greater attention to the rapid increases in energy consumption and energy intensity and implemented a series of energy efficiency policies to slow down energy consumption growth, improve energy efficiency, and reduce emissions. Since 2005, China's energy intensity has continuously declined, with energy intensity falling by 39.8% from 1.08 tce/10,000 2010CNY in 2005 to 0.65 tce/10,000 2010CNY in 2017, with an average annual growth rate of -4.1% (Figure 2b).

As the economy continues to grow steadily, China's total energy consumption has shown an overall growth trend over the last decade. However, due to a series of energy savings measures, the country's energy intensity has declined, resulting in a slowing growth rate of total energy consumption. The average growth rate of total energy consumption was 6.7% in the 11th FYP period while it was only 3.6% during the 12th FYP period (Figure 2b).

From a sectoral perspective, levels of development are different in the industry, buildings, and transportation sectors in China. Both the buildings and transportation sectors are still rapidly developing and will continue to increase energy consumption for the foreseeable future. The industry sector, with energy intensity and consumption both being quite high, continues to be the main sector for energy efficiency improvement in China.

With the adjustment of industrial structure, the elimination of backward production capacity, and the introduction of new technologies, the energy intensity of the industry sector in China continues to decline. The industry sector is the largest contributor to China's energy efficiency improvement and emissions reduction.

Specifically, in China’s industry sector, the country has entered the stage of pursuing high-quality development after years of fast growth. The growth of energy intensive industries has slowed down while new and technology intensive industries have emerged. Meanwhile, the campaign to remove outdated capacity has phased out less efficient production and driven efficiency improvement. As a result, China’s industrial energy intensity has declined at a greater rate than the world average, bringing energy consumption in the country’s industry sector to a plateau. The industry sector continues to be the greatest contributor to improving energy efficiency and achieving climate goals in China (see the section on Energy Efficiency in Industry for details).

In the buildings sector, China is in the process of rapid urbanization, which is not expected to slow down until around 2030 when urban population exceeds 70% of total Chinese population[20] [24]. As such, China's total building floor space and total building energy consumption will continue to increase. In addition, Chinese buildings today are not able to fully meet citizens’ growing demand for building services, so the per capita building energy use and building energy use per unit of floor space (i.e. building energy intensity) in China are also expected to grow. In the near- and mid-term, it is a tough challenge for China’s buildings sector to meet citizens’ demands while efficiently using energy and other resources in the process of urbanization (see the section on Energy Efficiency in Buildings for details).

In the transportation sector, China is the world's largest market for on-road motor vehicles, with fuel consumption in transportation accounting for more than 60% of the national total petroleum fuel use[21]. Since 2005, the Chinese government has implemented a series of fuel efficiency standards on new light-duty vehicles (LDVs, mostly cars) and heavy-duty vehicles (HDVs) with significant progress. At the same time, China is the fastest emerging market for new energy vehicles (NEVs). Transportation energy efficiency in China is improving in many respects (see the section on Energy Efficiency in Transportation for details).

20. According to R. Northam, urbanization is generally categorized into three stages: the initial stage when the urbanization rate is under 30%, the middle stage when the urbanization rate is between 30%-70%, and the late stage when the urbanization rate is above 70% (and normally under 90%).
21. Data source: the International Council on Clean Transportation (ICCT).

Technology Advancement Creating New Possibilities for Energy Efficiency

Improving energy efficiency plays an important role in achieving high-quality economic development in China. In addition to deploying commercially available, cost-effective energy efficient technologies, processes, production systems, and management systems to improve energy efficiency, China is also focusing on research and development to open up new energy efficiency opportunities, thus achieving coordinated energy, climate, and economic development.

The Ten Major Energy Conservation Projects Campaign in the 11th FYP period and the *12th FYP on Energy Conservation and Emissions Reduction* specify a number of key energy conservation projects. The implementation of these projects enabled the development and wide deployment of energy efficiency technologies such as district combined heat and power generation, waste heat utilization, energy saving in electric motor systems, energy system optimization, and green lighting [25][26]. Energy service companies (ESCOs), as the main players in the energy efficiency market, are also promoting the application of these technologies in carrying out energy performance contracting projects (see the section on Energy Efficiency Market for details). In the future, China will further develop and deploy advanced energy efficiency technologies for realizing a more energy efficient economy.

In recent years, China's policy support and investment has focused on emerging energy efficient technologies (see the section on Energy Efficiency Investment and Financing for details). The new technology revolution centered on the Internet of Things and artificial intelligence is changing the way of traditional production and energy use. Accelerating the development and promotion of new technologies is undoubtedly an important future direction for energy efficiency technologies and for the field of energy efficiency. In the near term, moving towards digitization and intelligent energy management could help deliver system-wide energy savings and fine-tuned savings. In the long term, production will change with the formation of fully digitized, intelligent and networked production methods; this could significantly increase productivity and industrial value, driving exponential growth in productivity.

Active Participation in International Energy Efficiency Cooperation

China actively plays a critical role in global efforts to address energy and climate change issues. China has been an active participant in and significant contributor to energy- and climate-related international exchange platforms and cooperation frameworks, including multilateral platforms such as the United Nations Climate Change Conference, the Clean Energy Ministerial, the Global Energy Efficiency Conference, the Global Climate Action Summit, the BRICS[22] Energy Cooperation, as well as bilateral exchanges such as the U.S.-China Energy Efficiency Forum, the Sino-German Energy Efficiency Working Group, and the China-Japan Energy Conservation and Environmental Protection Forum.

While China actively participates in international communication and cooperation for energy efficiency, it has also taken the initiative to align with other countries for more effective outcomes. This includes authoring the *G20 Energy Efficiency Leading Program*, which is the first China-led document under the G20 framework, initiating and leading the Green Belt and Road concept, establishing regional energy interconnection and promoting initiatives on electric vehicles proposed by China along with some other countries under the Clean Energy Ministerial mechanism.

International exchange and cooperation is a win-win approach to improving energy efficiency and addressing climate change. On the one hand, China can learn from international best practices in order to more effectively improve. On the other hand, China can use the "Chinese experience" to make positive impacts on other countries in order to work together to address the climate change challenge.

22. Brazil, Russia, India, China, and South Africa.

2. Energy Efficiency in Key Sectors

Energy Efficiency in Industry

Overview

China's industry is currently undergoing a transition from high-speed growth to seeking high-quality development. During this transition, the economic contribution of high energy-consuming industries has fallen sharply while the economic contribution of strategic emerging industries[23] has grown significantly. From 2006 to 2017, the average annual growth rate of industrial value added dropped from 11.4% to 6.4% and the share of industrial value added in GDP decreased from 42% to 34%[24]. In 2017, the strategic emerging industries grew by 11% compared to 2016, while energy intensive industries grew by only 3%[25]. At the same time, industrial energy consumption entered a plateau period, with the growth rate of energy consumption in high energy-consuming industries continuing to decline. The average annual growth rate of industrial energy consumption from 2010 to 2016 was only 1.8%, and industry's share of total energy consumption in the country dropped from above 70% to 66.6%. The average annual growth rate of energy consumption in the six highest energy-consuming industries dropped from 6.8% during the 11th FYP period (2006-2010) to 1.2% in the 12th FYP period (2011-2015) (Figure 5).

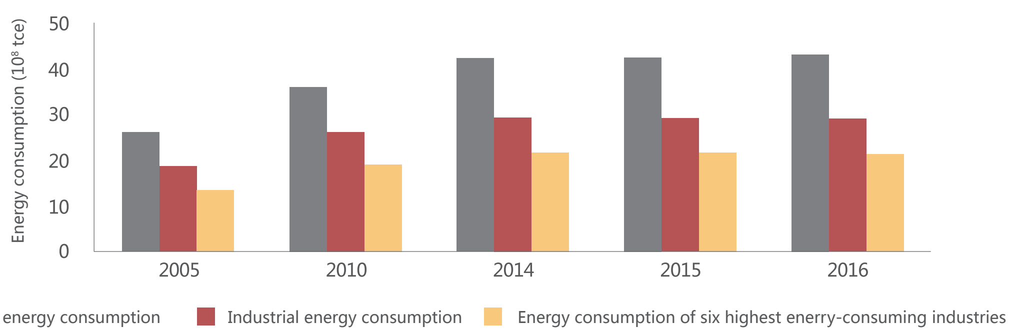


Figure 5 Energy consumption in China, China' s industry, and China' s six highest energy-consuming industries (2005-2016)

Source: *China Energy Statistics Yearbook 2017*

23. The strategic emerging industries include energy-saving and environmental protection industry, information technology industry, bio-technology industry, high-end equipment manufacturing industry, new energy industry, new materials production, and electric vehicle related industries.
24. China's industry sector has long been dominated by high energy-consuming industries. Although there is a tendency of pursuing high-quality development, overall, the growth of China's industrial value added is becoming slower and its share of GDP is declining largely due to the shrinking high energy-consuming industries.
25. Data source: Statistical Communiqués on National Economic and Social Development.

China's industrial energy intensity[26] is declining the most rapidly of any country in the world. In the 16 years from 2000 to 2016, the global industrial energy intensity fell by less than 20%, while that in Chinese industry fell by 43% from 2.35 tce/10,000 CNY[27] to 1.34 tce/10,000 CNY in the ten years from 2006 to 2016 [14].

The application of energy efficient technologies, energy saving measures such as energy management, and the phase-out of inefficient manufacturing facilities has resulted in a significant reduction in energy consumption per unit of production in China. Figure 6 shows that the energy consumption per unit of product in six major industries in China decreased between 2010 and 2016. Energy efficient technologies have contributed 50.6% and 34.1% of China's industrial energy savings, respectively, during the 11th FYP period (2006-2010) and the 12th FYP period (2011-2015). The elimination of outdated production capacity has also played an important role in China's industrial energy efficiency. Between 2006 and 2016, retiring backward production capacities in the coal, steel, cement, and flat glass industries alone saved 326 million tce of energy, equivalent to 11.2% of China's total industrial energy consumption in 2016 [27].

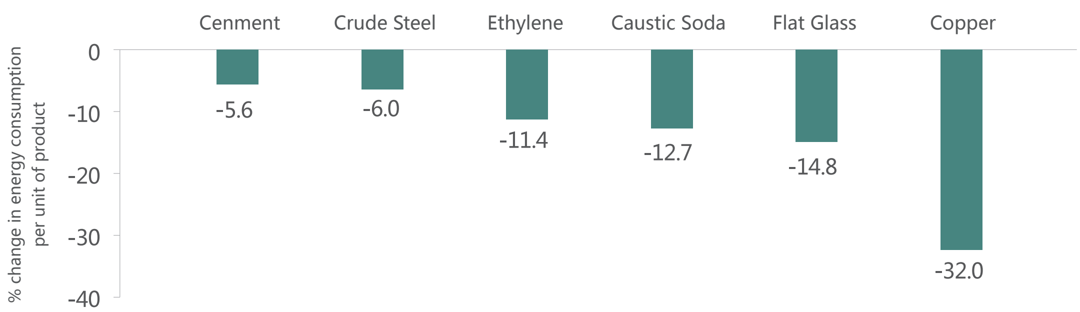


Figure 6 Reduction in China's energy consumption per unit of product in six major industries (2010-2016)
Source: WANG Qingyi, *Energy Data 2017*

The industry sector has been the largest contributor to China's energy saving goals and energy efficiency improvement. During the period from 2006 to 2010, China's industrial energy intensity fell by 26% while the country's overall energy intensity fell by 19.4%. From 2011 to 2015, the overall energy intensity fell by 18.4% and industrial energy intensity fell by 27%. For many years, the decline in China's industrial energy intensity has been greater than the decline in its overall energy intensity. Over the past ten years from 2006 to 2015, the decline in

26. The energy consumption per unit of industrial value added.
27. Unless otherwise stated, the monetary value in the report refers to current year price.

China’s industrial energy intensity generated energy savings of 1.4 billion tce[28], providing a large opportunity for the other sectors that need strong growth in energy use.

Trends and Highlights

Industrial energy efficiency remaining top priority of China's energy conservation strategy

From a global perspective, although China's energy intensity has declined significantly in recent years, the energy consumption per unit of product in China’s industry sectors, especially in the high energy-consuming industries, are still behind international advanced levels, with a gap of 10%-30% in industries such as steel, cement, ethylene, flat glass, caustic soda, and thermal power (Figure 7). Industrial energy efficiency improvement still has great potential, which is the top priority of China's energy saving efforts.

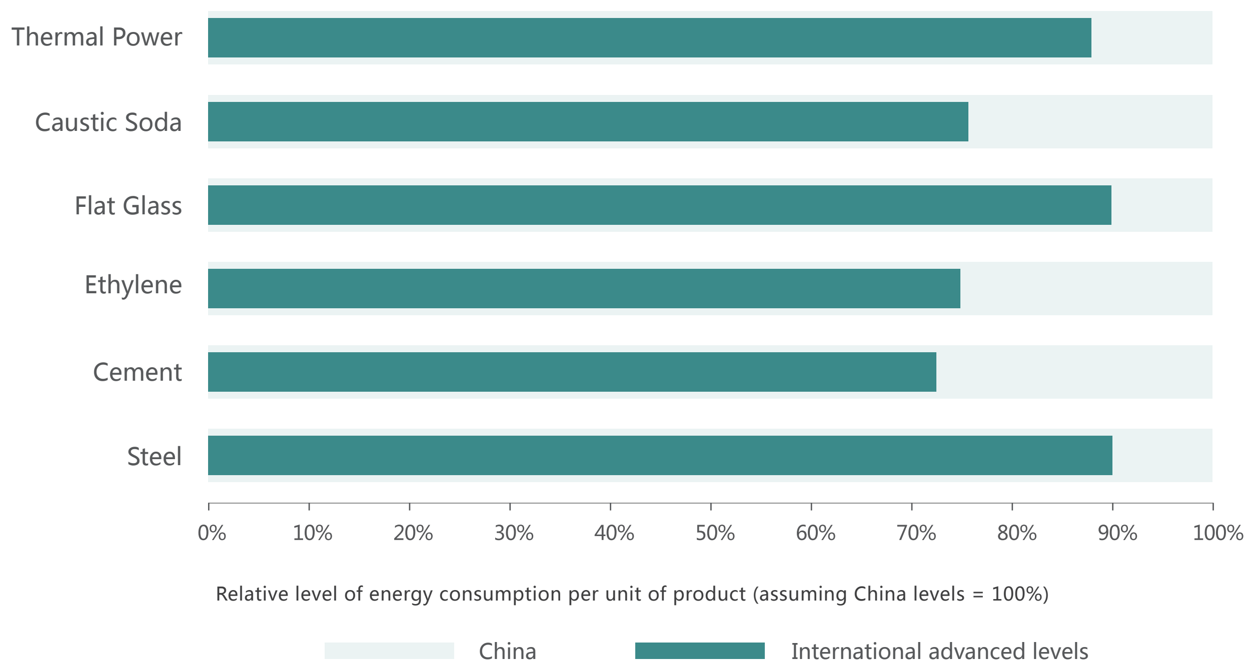


Figure 7 China’s typical industrial energy consumption per unit of product relative to international advanced levels
Data source: WANG Qingyi, *Energy Data 2017*

In terms of development stage, China is currently undergoing a rapid urbanization process with continuing growth of the buildings and transportation sectors. The roadmap study of *Reinventing Fire: China* evaluated two scenarios

28. Data source: *China Energy Statistics Yearbooks*.

of energy consumption and production to 2050. In its reference scenario, this study showed that by 2050, China would add about 30 billion more square meters (m^2) of new buildings and increase passenger and cargo transportation demand by five times, consuming over 5 billion tce of primary energy, which would bring an unprecedented challenge in containing the country's total energy consumption. In the advanced Reinventing Fire scenario, China's carbon dioxide (CO_2) emissions associated with energy consumption would peak in 2025, while CO_2 emissions in the buildings and transportation sectors would peak in 2029 and 2035, respectively, to meet their strong demand. Energy-related CO_2 emissions from the industry sector would continue to decline to create enough growth opportunities for the buildings and transportation sectors (Figure 8). Based on the assumptions of this scenario, China's industry sector would play an important role in energy saving and CO_2 emission reduction [28].

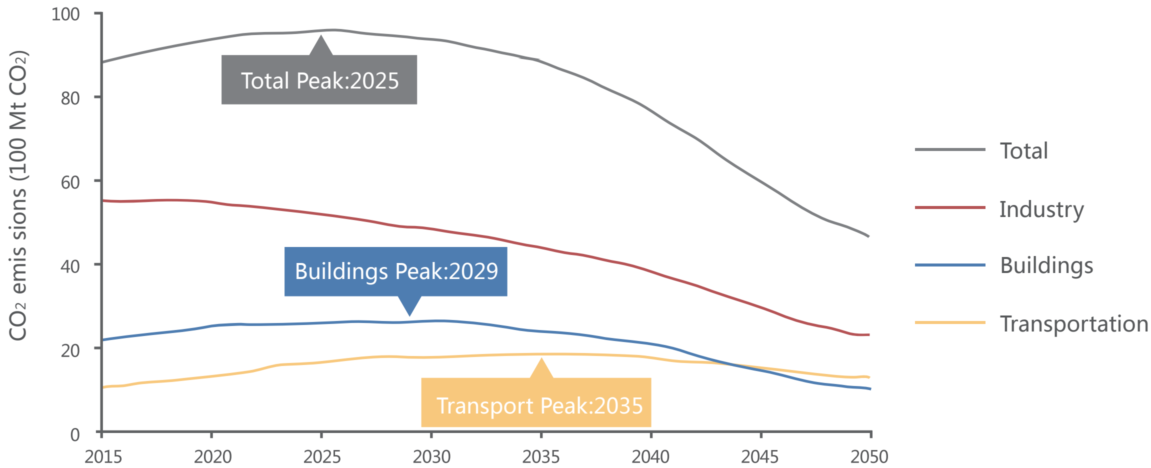


Figure 8 Energy-related CO_2 emission curves under the Reinventing Fire scenario (2015-2050)

Sources: ERI, LBNL, RMI. 2016. *Reinventing Fire: A Roadmap for China's Revolution of the Consumption and Production of Energy to 2050, Executive Summary.*

Energy management systems beginning to take effect

The concept of energy management system (EnMS) was introduced to China at the beginning of this century. In 2008, a local standard *Energy Management System Requirements in Shandong Province* was introduced in Shandong Province and a national standard of the *Energy Management System Requirements in China* was issued in 2009. The 2012 amendment made this national standard fully align with the international standard of ISO 50001:2011. The energy management systems have been incorporated by the NDRC and other relevant departments as an important component in the Energy Conservation and Low Carbon Actions in Top-10,000 Enterprises program during the 12th FYP period (2011-2015). Since then, EnMS has been recognized in energy-related government regulations, plans, and programs as an important measure to enhance energy efficiency management and reduce energy consumption. As of June 2018, nearly 10,000 enterprises have established energy management systems. EnMS certification has been issued to 2,824 of these companies[29]. In June 2017, China issued eight energy management best practice cases, all showing that after establishing energy management systems, energy consumption dropped significantly [29].

China categorized the roles of energy management system into “four mechanisms” and “three continuous improvements”, namely: the mechanism of helping enterprises build up energy saving compliance capacity, the mechanism of whole-process control of energy use, the mechanism of encouraging energy saving technological improvement, and the mechanism of promoting energy saving awareness and culture; as well as continuous improvement of energy efficiency, continuous optimization of energy management, and continuous improvement of energy performance. China's practice proves that energy management systems can be based on scientific concepts and methods with clear energy saving effects, which can help improve energy efficiency in industrial enterprises. However, considering the large number of industrial enterprises in China and their energy efficiency improvement potential, there is still significant work to be done related to energy management systems, especially in the areas of standardization, consultation, certification, incentive policies, enterprise awareness, and responses.

Green development gradually becoming the main theme

Pursuing green[30] development and promoting green growth has become a common among the world's major economies, and is valued by China as an inevitable way to enhance international competitiveness. In general, China's industry has not yet transitioned out of the high-input, high-consumption, and high-emissions development mode. This type of development mode consumes enormous amounts of resources and energy, which results in serious environmental problems. Acceleration of green industrial development will help to address these environmental issues.

29. Source: there is no official data about the national number of EnMS certification; data are collected and calculated from multiple government documents, mostly retrieved from http://gxt.jiangsu.gov.cn/ and http://www.wheitc.gov.cn/.
30. Of efficiency, environmental friendliness, and sustainability.

China's green industrial development refers to restructuring and transforming the industry to be green and low carbon through measures such as structural adjustment, energy efficiency improvement, resource use reduction and recycling, and fuel substitution in order to create a green industrial system, save energy, reduce production costs, improve economic performance, and to enhance the international competitiveness of China's industry, ultimately leading to more harmonious development of industry and environment.

As an important part of green industrial development, a green and high-efficiency manufacturing industry can be established through improving energy efficiency of traditional manufacturing capabilities, technical improvement, carrying out demonstration of industrialization of key energy efficiency and environmental protection technologies, developing a system of standards for green products[31], green facilities[32], green industrial parks[33], and green supply chains[34], and conducting green development assessments to effectively promote green and efficient development of China's manufacturing industry. By 2020, China plans to develop and promote 10,000 kinds of green products, build 1,000 green demonstration facilities and 100 green demonstration industrial parks, aims to have energy consumption in some key chemical facilities begin to decline, and anticipates to decrease emission intensities of major pollutants in key sectors by 20%. The goal is for energy consumption per unit of product to catch up to the world's advanced level and to establish a green manufacturing system by 2025 [30].

Outlook

Structural adjustment to lay foundation for industrial energy efficiency improvement

In terms of China's industrial structure, the share of industrial value added in national GDP has shown a downward trend in recent years, and the industry-supporting service sector[35] is accelerating its development. It is expected that in the 13th FYP period (2016-2020) and future years, the service sector will play an increasingly strong role in supporting China's economic development, and the trend of the industry sector being dominated by lighter

31. Green products refer to products that consume less energy and water, produce fewer emissions and toxic substances, and are renewable and recyclable throughout their life cycle.
32. A green facility is a facility that achieves efficient land use, cleaner production, waste recycling, and low carbon energy.
33. A green industrial park refers to an industrial park where energy, resources, infrastructure, industrial structure, ecological environment, and operational management all meet green development indicators.
34. The green supply chain refers to a sustainable management model that considers environmental impacts and resource efficiency throughout the supply chain. The purpose is to achieve minimum environmental impact and optimal resource utilization throughout the entire chain from the material acquisition, processing, packaging, warehousing, transportation, and consumption to end-of-life treatment.
35. The industry-supporting service sector generally refers to the supporting services directly related to the industry sector. It is an emerging sector developed independently from the service component within the industry sector. This includes service industries such as the financial and insurance industry, software and information service industry, scientific research and technological service industry, and others that are closely related to commercialization activities.

industries will become more apparent. The trend is not only in line with the characteristics and internal needs of China's industrial development stage, but is also an important way to optimize energy usage and improve energy efficiency.

Looking at China’s internal industrial structure and comparing it with developed countries, the proportion of traditional high energy-consuming industries is higher, and some emerging industries (such as strategic emerging industries and high-tech manufacturing) are still at an initial stage. Future industrial growth is expected to shift from traditional high energy-consuming industries to emerging industries, which will improve industrial structure and promote industrial quality and efficiency.

From the perspective of industrial product structure, China ranks the first of the world in the output of more than 200 kinds of industrial products [31], but most of these products are low-end industrial products with high energy consumption and low value added - only a few high value-added industrial products are among the 200 kinds. In the future, Chinese industrial enterprises can help China's energy productivity achieve a significant increase by enhancing their technology portfolio, pursuing technology competitiveness in the market, and reducing resource and energy consumption.

Coordinated development to become key to industrial energy efficiency improvement

At present, China's industry has issues such as uneven regional development, inefficient energy consumption, and low resource recycling. Coordinated development among regions, industries, and sectors is the key to improving industrial energy efficiency and optimizing industrial structure.

China is continuously urbanizing, which provides a good opportunity for coordinated regional development of the industry sector. Efficient resource and energy utilization can be achieved through establishing interconnected industrial development systems between regions, strengthening coordinated supply chains, and promoting cooperation between enterprises, industries, and industrial parks across regions for integrated collaborative development. This type of development has taken place in the Yangtze River Delta region, the Pearl River Delta region, and the Beijing-Tianjin-Hebei region, and is expected to spread to many other regions.

The coordinated development of regional energy systems is also an important part of improving energy efficiency.

In the future, various energy resources such as oil, coal, natural gas, and electricity should be integrated to establish regional comprehensive energy systems in different areas. This will help realize complementary and mutual benefits of different energy sources and promote energy efficiency improvement while meeting diversified energy demand and promoting efficient ways of energy consumption.

Strengthening resource recycling is another important development area for China’s industry sector. Because of rapid increases in both cumulative consumption of major resource products and the stock inventory of durable consumer goods, China's supply of recycled resources has a strong growth potential in the coming years (Figure 9). Strengthening resource recycling can significantly reduce the consumption of primary resources and effectively promote the transformation of the economy towards a more efficient mode of development.

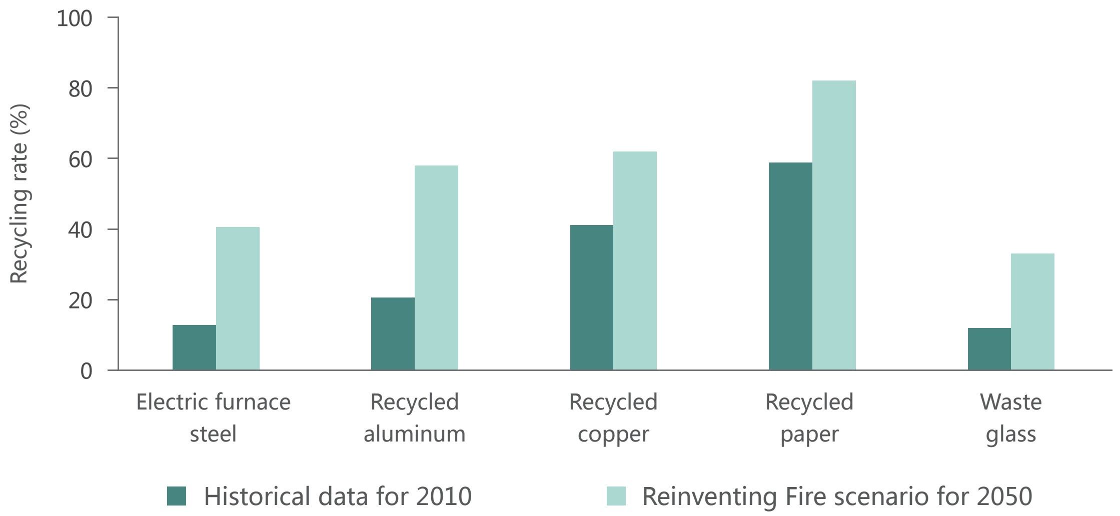


Figure 9 **Potential recycling rates of some renewable resources under the Reinventing Fire scenario (ideal recycling rate vs. historical data)**
Data source: XIONG Huawen and FU Guanyun, *Reinventing Fire: China - Industry Volume*, 2017

Enterprise motivation to be future focus of industrial energy efficiency policies

China's industrial energy conservation policies and regulations have historically been less focused on utilizing market mechanisms to mobilize enterprises' energy saving motivation and to overcome the obstacles in enterprises’ energy saving decisions. China has recently initiated some programs to stimulate enterprise intrinsic motivation in their energy efficiency projects, such as the Chinese Energy Efficiency Top Runner program.

The Energy Efficiency Top Runner program was originated in Japan. Based on the energy efficiency levels of Japan's best available energy saving products, the top runner energy efficiency standard values (EE values) are determined. The EE values are continuously improved over a certain number of years to encourage enterprises to achieve the corresponding energy efficiency goals, drive substantial progress in enterprise energy saving technologies, guide the healthy development of the entire industries, and to promote product structure upgrades.

Learning from Japan's experience, China has expanded the program scope from products alone to products, enterprises, and energy-consuming entities. The Chinese Energy Efficiency Top Runner program[36] was officially kicked off in December 2014, but is still in the early stage of development. In order to fully achieve the program's effectiveness in the future, efforts shall be made to further clarify program objectives, improve the incentives and penalizing regulations, expand the scope of covered products, and to improve financial subsidies and tax credit policies, all aiming to motivate enterprises in technology innovation and pursuing higher energy efficiency standards. Through improved public awareness and consumer subsidies, the program can increase leading enterprises' market competitiveness. It is expected that the program will play a greater role in improving China's energy efficiency.

Advanced technology application to boost industrial energy efficiency improvement

With the rapid development of information technology in recent years, cross-sector integration and innovation between information technology and traditional industries has become a global trend. The new industrial revolution centered on smart manufacturing is changing industrial production approaches and the efficiency of energy utilization. Chinese enterprises have achieved remarkable results in energy efficiency improvement with the application of such technologies.

For example, a leading engineering machinery manufacturing company in China utilizes many cutting-edge technologies to improve production efficiency such as information-based intelligent manufacturing, industrial Internet of Things, and intelligent and automatic production lines. It also uses machine learning and artificial intelligence and other big data analysis and data mining technologies to provide production process control and optimization. The production efficiency of the company has increased by more than 24%, production cycles have

36. China's Energy Efficiency Top Runner program recognizes products and energy-consuming enterprises or entities that have achieved the highest available energy efficiency levels within comparable range. The implementation of the Energy Efficiency Top Runner program is helping to motivate society to pursue energy conservation and emissions reduction, developing energy conservation and environmental protection industries, saving energy, and protecting the environment.

shortened by 28%, production errors have decreased by 40%, the defective product rate has decreased by 14%, logistics operation efficiency has increased by more than 18%, delivery speed has increased by 12%, and labor costs were reduced by about 20%. The company's overall manufacturing operating costs were reduced by 28% and production energy use decreased by about 7% [32].

In the future, industrial production is expected to utilize advanced technologies to improve energy efficiency. In the near-to-medium term, smart energy and energy interconnection systems can be applied in the industry sectors. Through the application of energy information technologies and intelligent management, systematic, fine-tuned, and digital energy savings can be further explored. In the long run, energy efficiency can be improved through digital, intelligent, and networked manufacturing methods, which will greatly increase production efficiency and industrial value added, and promote the growth of energy productivity. Using a new generation of advanced technologies such as Internet of Things, artificial intelligence, cloud technology, energy storage technology, and 3D printing, green and intelligent manufacturing can be achieved, changing production models, improving the efficiency of equipment, process, logistics and personnel management, and reducing production costs, thus directly or indirectly improving energy efficiency and productivity (Box 2).

Box 2　Advanced technologies and their roles in improving industrial energy efficiency

Internet of Things	Applied in the manufacturing sector' s energy management and control systems. By using a real-time feedback system of electricity consumption, it can reduce equipment electricity consumption by 10%-15%.
Artificial intelligence	By utilizing machine learning in the factory data centers, it can help reduce energy use by 40% in cooling systems and improve overall energy efficiency by 15%.
Cloud technology	By incorporating cloud technology into intelligent air conditioning (AC) systems, one AC unit can save 4.7 kilowatt-hours (kWh) of electricity per day.
Energy storage	It will support China' s energy electricity use equivalent to 45 million kWh of installed capacity addition. By 2030, the share of renewable sources is expected to reach 20% by 2030.
3D printing	Through the application of 3D printing technologies, alternative materials and recycling can be further adopted in machinery, automobile, buildings, and garment sectors to significantly reduce energy consumption.

Source: private communications with multiple enterprises

Energy Efficiency in Buildings

Overview

China's urbanization process is a critical factor affecting energy efficiency in the Chinese buildings sector. China is still in the process of rapid urbanization. From 1978 to 2017, the proportion of urban population in China increased by 1.0% annually. In 2020, the resident urban population will account for 60% of the total population [33]. It is expected that China's urbanization rate will reach around 70% by 2030 [24]. Meeting the growing demand for building services while avoiding excessive energy consumption is a serious challenge faced by China's buildings sector.

In terms of total buildings stock, China's total building floor space in 2015[37] reached 61.3 billion m², of which public buildings were about 11.3 billion m² (18.4%), urban residential building area was 24.8 billion m² (40.5%), and rural residential buildings were 25.2 billion m² (41.1%) (Figure 10). In 2015 China's total building energy consumption was 860 million tce, accounting for roughly 19.9% of the country's total energy consumption (Figure 11).

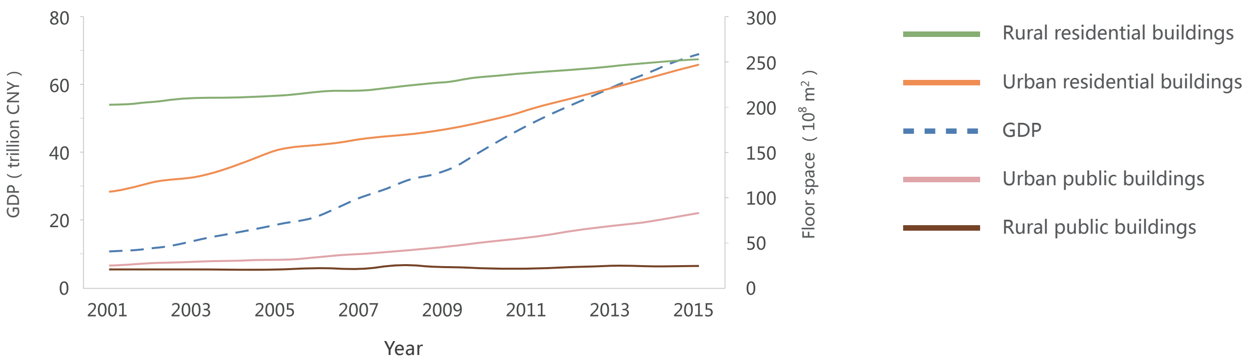


Figure 10 GDP and building floor space in China (2001-2015)

Data source: Based on *China Statistical Yearbooks*.

37. As of late 2018, 2015 data is the latest publicly available statistics on the building sector from official sources in China.

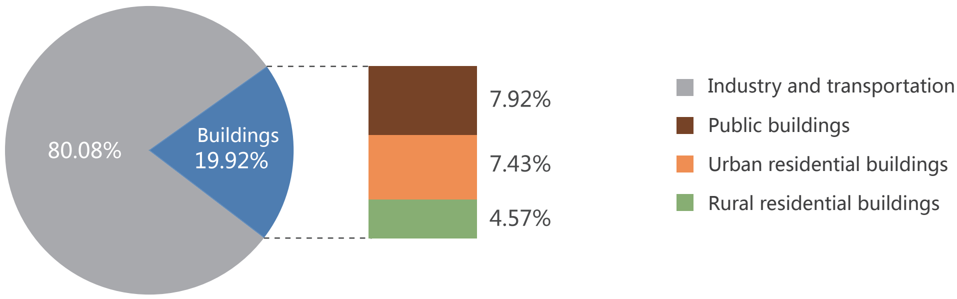


Figure 11 China building energy consumption by sectors (2015)
Data source: Based on *China Statistical Yearbooks.*

Between 2001 and 2015, urban residential buildings accounted for 36%-39% of China's total building energy consumption. Public buildings accounted for 37%-41%, and rural residential buildings stayed relatively stable at around 23% (22.6%-23.6%) (Figure 12).

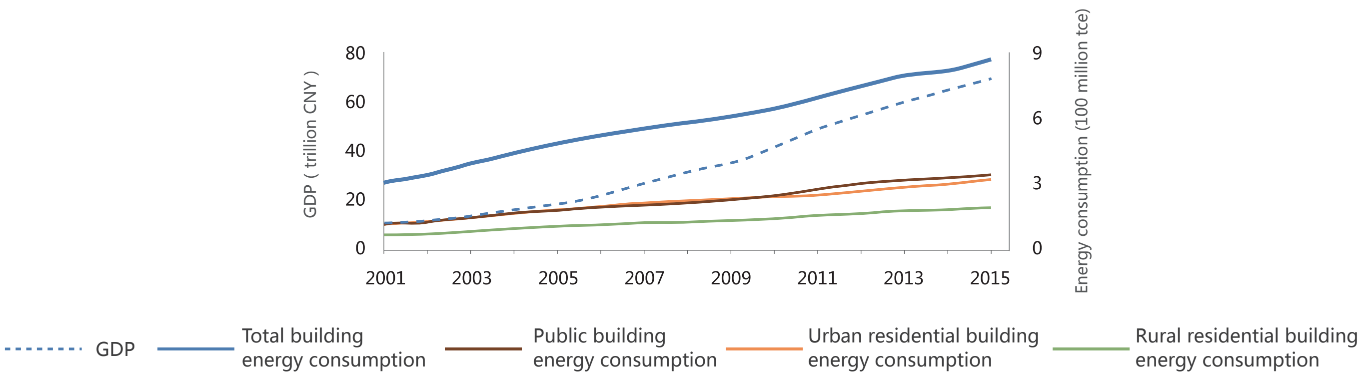


Figure 12 China building energy consumption trend (2001-2015)
Data source: Based on *China Statistical Yearbooks* and *China Energy Statistical Yearbooks.*

Trends and Highlights

China's urbanization continuing to drive up building energy consumption

China's urbanization process has been continuously driving the rapid growth in total building construction and building energy consumption. From 2001 to 2015 with economic growth, China's floor space of urban residential buildings and public buildings expanded by 2.31 and 2.33 times, respectively. Total building energy consumption increased by 2.8 times, while energy use in urban residential buildings, rural residential buildings, and public buildings increased by 2.69, 2.70, and 2.91 times, respectively (Figure 10 and Figure 12).

As a developing country, China's building service and comfort levels have a significant demand gap compared with developed countries. China's per capita building energy consumption is much lower than that of developed countries, and the building energy intensity[38] is only about 1/3 that of the United States (Figure 13). Due to a number of factors, such as improved residential building indoor comfort and building services, southward movement of central heating supply (i.e., more southern areas in China are beginning to have central heating), increasing demand for air conditioning in warm climatic zones, transformation of building energy use modes, and "urbanization" of rural energy use, China's building energy consumption will continue to have strong growth in the future.

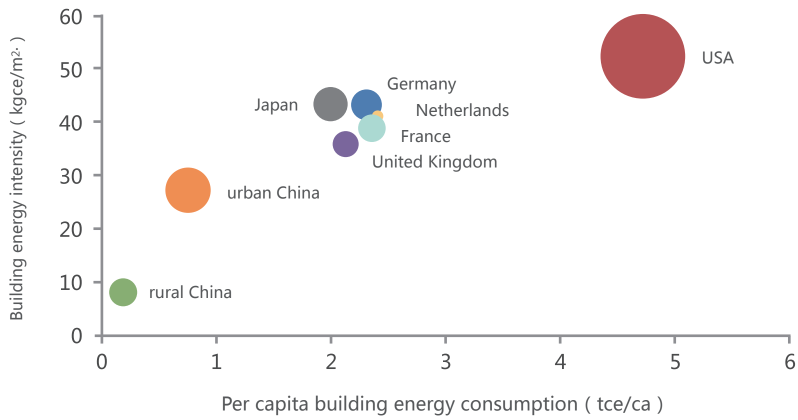


Figure 13　Building energy consumption levels in China and other countries (2015)

Note: Dot size represents total building energy use of the country.

Data source: HU Shan, *A study of China urban residential building energy consumption compared with the developed counties*, Tsinghua University Thesis, 2013; Japan: The Energy and Modeling Center, the Institute of Energy Economics, Japan, *Handbook of Energy & Economic Statistics in Japan*, 2011; The United States: Energy Information Administration, *Building Energy Databook 2010*; EU: European Commission, Eurostat.

China's building energy efficiency policies have achieved significant results [34], such that the annual growth rate of China's total building energy consumption demonstrated an overall decline between 2001 and 2015. Although in the recent five years, the mean of annual growth rates of China's building energy consumption reduced by 5 percentage points compared with that between 2001 and 2006, the growth rate is still as high as 6.1% (Figure 14). It can be expected that total energy consumption of China's buildings sector will maintain high growth.

38. Energy consumption per unit of floor space.

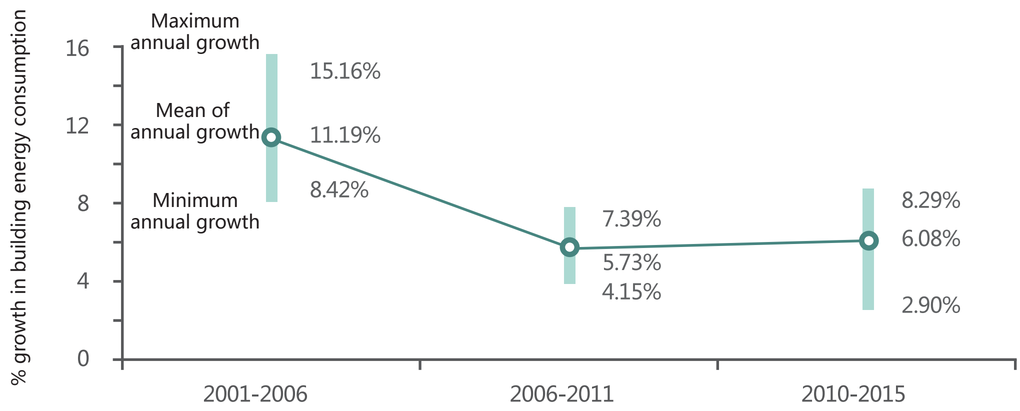


Figure 14 Growth rates of building energy consumption in China 2001-2015

Source: *China Energy Statistical Yearbooks*.

Urban-rural difference in energy demand causing deviation in energy mix and intensity

From 2001 to 2015, energy intensity of urban residential buildings increased by 16.6%, and that of rural residential buildings increased by 2.2 times. Recently, the energy intensity of urban residential buildings began to stabilize, while rural residential building energy intensity increased rapidly. The mean of annual changes in energy intensity of urban residential buildings from 2010 to 2015 was -0.3% while that of rural residential buildings was around 4.6% (Figure 15).

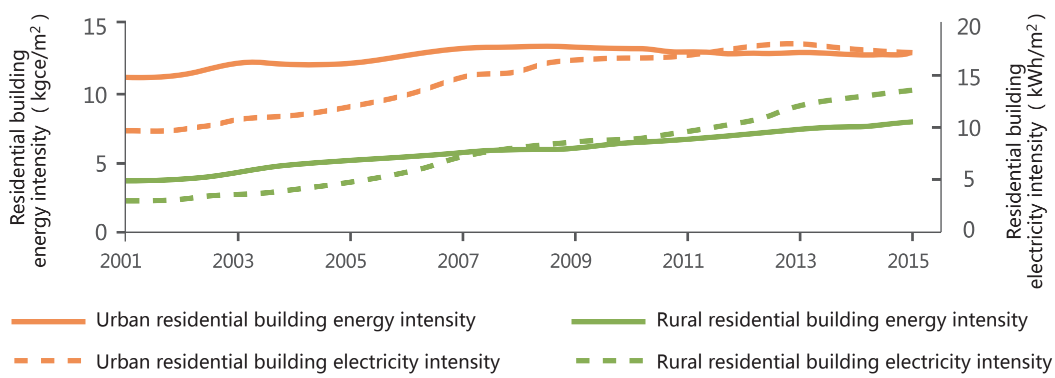


Figure 15 Residential building energy intensity in China's urban and rural areas (2010-2015)

Data source: Based on *China Statistical Yearbooks.*

In terms of building energy consumption structure, energy use in rural residential buildings is still dominated by non-commercial energy sources[39] such as biomass energy for cooking and heating (crop straws, grass, fire wood, and animal waste are most commonly used). In 2013, non-commercial energy use in rural areas accounted for 63% of total rural energy consumption[40]. There are seven energy sources used in rural households, in which biomass, coal, and electricity were the most consumed, accounting for 61%, 15%, and 11%, respectively (Figure 16). Only recently the share of non-commercial energy consumption in rural residential building energy consumption began to fall.

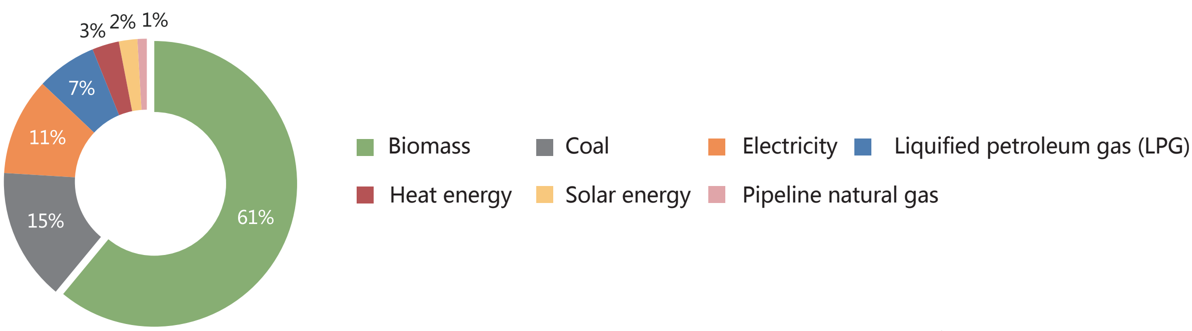


Figure 16 Figure 16 Energy use mix in rural residential buildings (2013)[41]

Data source: National Academy of Development and Strategy, Remin University of China. *Research Report on Residential Energy Consumption in China (2015)*. May 2016.

In contrast to the energy consumption structure in rural households, urban residential buildings consume a large proportion of energy in the form of heat. For example, heat consumption in urban residential buildings in 2015 accounted for 58% of total energy use, followed by electricity, which accounted for 23% (Figure 17).

In general, the share of electricity in both rural and urban residential building energy consumption increased significantly from 2001 to 2015. Electricity consumption in rural buildings increased by 4.6 times, significantly higher than the 80% increase in urban residential buildings (Figure 15).

39. The non-commercial energy sources include agricultural residues, human and animal waste, and other sources of energy that are not traded as commodities. Because they are not for commodity trading, it is difficult to calculate their amount in the energy balance. They are usually biomass such as straw, grass, fuel wood, and livestock manure. They also include non-commodity biogas. In recent years, however, biogas is gradually turning into a commercial energy in some rural areas.

40. Data source: *Research Report on Residential Energy Consumption in China (2015)* by the National Academy of Development and Strategy, Remin University of China, available at http://nads.ruc.edu.cn/upfile/file/20160524085312_906914_35342.pdf.

41. Building energy consumption here refers to primary energy consumed by buildings, where heat supply refers to municipal central heating (this applies throughout the rest of the report). To note, the latest statistics on the energy use in rural residential buildings are only available through 2013.

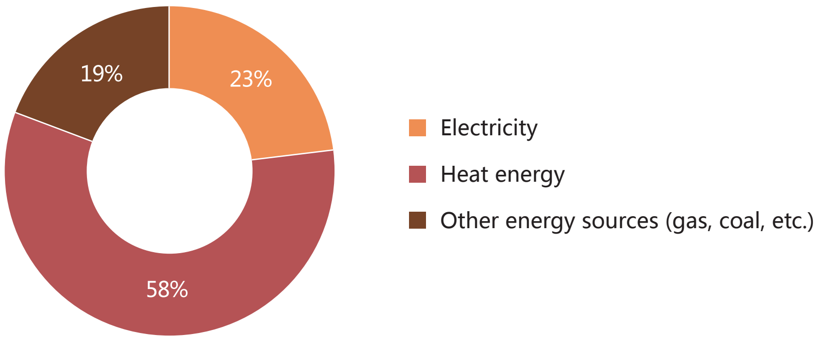


Figure 17 Energy use mix in urban residential buildings (2015) [42]
Data source: *China Energy Statistical Yearbooks.*

New building efficiency improving with standards while existing buildings being retrofitted

For new buildings, China uses two measures to promote energy efficiency: improving energy efficiency design standards and strengthening enforcement of standard implementation.

As of 2017, the energy efficiency standards for new buildings in urban areas in China have all been published, covering energy efficiency design standards for urban residential buildings and public buildings in four climatic zones: severe cold, cold, hot summer and cold winter, and hot summer and warm winter. Mandatory standards for meeting a 75% energy saving target for new buildings have been enforced in Beijing, Tianjin, Hebei Province, Shandong Province, and Sinkiang[43].

In addition to developing and publishing standards, enforcement of the new building energy efficiency standards has also improved. From 1996 to 2005, only northern China where central heating is provided was required to implement energy efficiency standards in new buildings. Since 2005, the Ministry of Housing and Urban-Rural Development (MOHURD) and provincial departments of Housing and Urban-Rural Development have carried out special annual supervision and inspection of building energy efficiency. After strengthening supervision and

42. "Other energy sources" here include district/distributed energy, such as residential district heating from coal and/or gas.
43. The 75% mandatory building energy efficiency requirement is the "fourth step" in China's building energy savings which started with the *Design Standard for Energy Efficiency of Residential Buildings (on Heating for Residential Buildings)* JGJ26-1995 published in 1996. This standard specifies that building energy efficiency should be improved by 30% in each step from the last step, with the very beginning baseline of energy consumption between 1980 and 1981. The 30% improvement was the first step and the standard referred to as the building energy efficiency 30% standard. The second step was to save an additional 30% from the first step with the cumulative savings (still compared with the 1980-1981 baseline; same below) calculated as 30% + (1-30%) × 30% = 51%; the requirement referred to as the building energy saving 50% standard. The third step was to save an additional 30% from the second step, with cumulative savings calculated as 51% + (1-51%) × 30% = 66%, referred to as the building energy saving 65% standard. As such, the fourth step is referred to as the building energy saving 75% standard, i.e. 66% + (1-66%) × 30%, in which the heating energy consumption during a heating season should be below 6.25 kgce/m².

inspection, the energy efficiency design standard implementation rate in China during the construction phase has increased significantly from 21% in 2005 to over 95% in 2010 (Figure 18). In 2015, the implementation rate of energy efficiency design standards for new buildings in urban areas reached 100%[44]. From 2001 to 2015, the cumulative floor space additions of energy efficient buildings totaled 7 billion m^2, and energy efficient buildings accounted for more than 40% of total urban residential building area[45]. Due to tougher energy efficiency standards and more effective enforcement, China's building energy efficiency has been improving steadily.

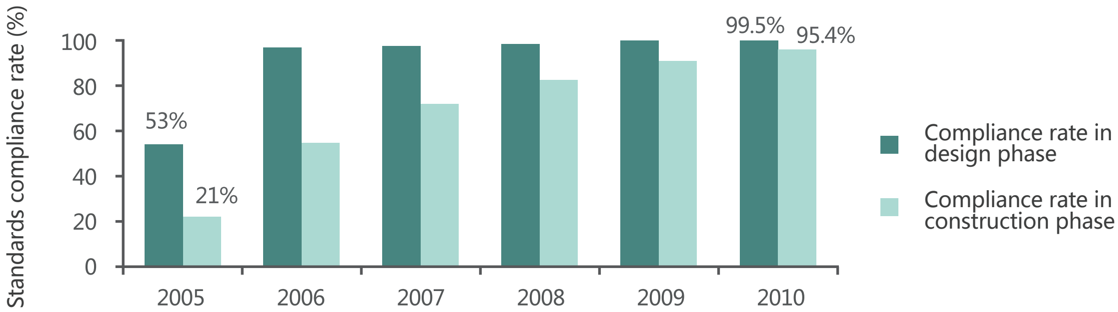


Figure 18 Implementation rate of energy efficiency standards for new buildings in urban China (2005-2010)
Data source: collected from multiple annual reviews and news from MOHURD.

The green building energy efficiency design standards demonstrate sustainability concepts in the design process. In addition to satisfying building functions, a green building can achieve maximum resource savings (energy saving, land use saving, water saving, and building material saving) throughout its life span, protect the environment and reduce pollution, and provide residents with healthy and efficient use of space[46]. In China's provincial capitals, green building standards have started to be broadly implemented in subsidized housing projects, government-invested public welfare buildings, and large public buildings. The green building standards have also began to be implemented in Beijing, Tianjin, Shanghai, Chongqing, Jiangsu Province, Zhejiang Province, Shandong Province, and Shenzhen, developing more than 1 billion m^2 of total green building floor space. As of 2017, a total of 7,235 construction projects in China have been recognized with green building certifications,

44. From MOHURD random inspection results in Beijing, Guangdong Province, Hebei Province, etc., mostly retrieved from http://search.mohurd.gov.cn/?tn=mohurd&lastq=%24wstquerystring%24&sort=last-modified+desc&rn=10&auth_info=&table_id=%24wsttableid%24&pn=0&query=%E6%96%B0%E5%BB%BA%E5%BB%BA%E7%AD%91%E8%8A%82%E8%83%BD%20100%25&ty=a&ukl=&uka=&ukf=&ukt=&sl=&ts=&te=&upg=0.
45. Data source: MOHURD, *13th FYP on Building Energy Efficiency and Green Building Development, February 2017*, available at http://www.mohurd.gov.cn/wjfb/201703/W020170314100832.pdf.
46. Compared with the energy efficiency design standards for new buildings, green building energy efficiency design standards cover overall and specific requirements for both building-related energy savings and resource savings including water savings, efficient land use, and building materials savings, and so on.

with more than 800 million m^2 of total floor space.[47]

For existing buildings, large-scale energy efficiency retrofits for residential buildings in northern China and public buildings have been carried out. This has significantly improved energy efficiency in existing buildings.

Since 2007, China has begun to implement energy efficiency retrofits in the northern area for non-energy-efficient buildings where central heating is provided. By 2015, central heating metering and energy efficiency retrofits had been carried out in 990 million m^2 of existing residential buildings, benefiting more than 15 million households. Comfort levels of old homes have been significantly improved. More than 6.5 million tce of energy was saved per year [48].

In China's northern central heating provinces, from 2001 to 2015, heating energy intensity[49] in urban buildings was significantly reduced. Although building construction increased continuously, the significant reduction of heating energy intensity effectively slowed the growth of total heating energy use. From 2002 to 2015, the heating energy intensity dropped significantly from 39.2 kgce/m^2 to 17.9 kgce/m^2, a drop of 54.5% (Figure 19). The heating floor space increased by 4.32 times, while heating energy consumption increased 97% during the same period (Figure 20).

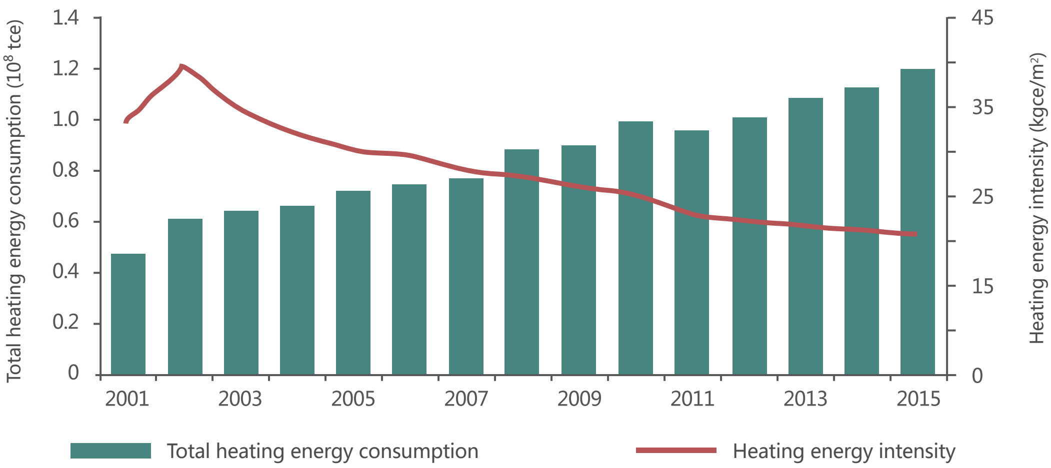


Figure 19 **Total heating energy consumption and heating energy intensity of northern urban area in China (2001-2015)**
Data source: *China Statistical Yearbooks.*

47. Data source: collected from multiple announcements by MOHURD, retrieved from http://search.mohurd.gov.cn/?tn=mohurd&lastq=%24wstquerystring%24&sort=last-modified+desc&rn=10&auth_info=&table_id=%24wsttableid%24&pn=0&query=%E7%BB%BF%E8%89%B2%E5%BB%BA%E7%AD%91%E8%AF%84%E4%BB%B7%E6%A0%87%E8%AF%86%E9%A1%B9%E7%9B%AE%20%E5%85%AC%E5%91%8A&ty=a&ukl=&uka=&ukf=&ukt=&sl=&ts=&te=&upg=0.
48. Data source: MOHURD, *13th FYP on Building Energy Efficiency and Green Building Development*, February 2017, available at http://www.mohurd.gov.cn/wjfb/201703/W020170314100832.pdf.
49. Heating energy consumption per unit floor space.

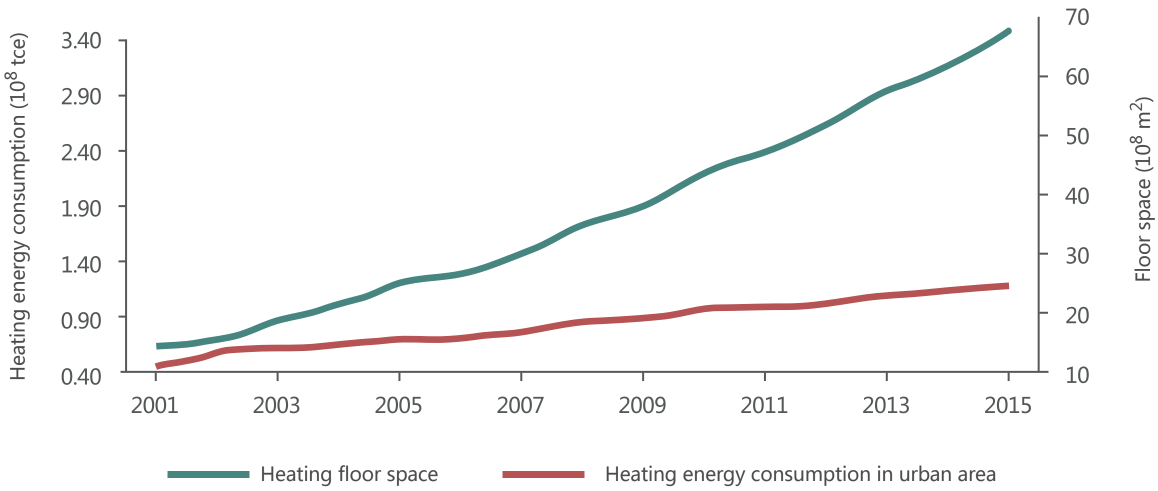


Figure 20 **Urban heating energy consumption and heating floor space (2001-2015)**

Data source: *China Statistical Yearbooks and China Energy Statistical Yearbooks.*

As of 2017, China has installed dynamic monitoring platforms for public building energy consumption in 33 provinces, and conducted online monitoring for energy use of more than 9,000 buildings. The energy saving regulatory systems and energy efficiency retrofits are installed at 233 colleges, 44 hospitals and 19 research institutes as pilot projects. Public building energy efficiency retrofit pilot projects of 69.6 million m^2 have been implemented in 29 cities including Beijing, Tianjin, and Shijiazhuang, saving more than 15% of energy used and driving retrofits floor space in other buildings to reach 110 million m^2 nationwide. In addition, building envelope retrofits projects for 22 million m^2 of existing public buildings, heat energy metering retrofits in 9.5 million m^2 of northern public buildings, and air conditioning and ventilation retrofits projects in 10 million m^2 of floor space have been implemented in public buildings. From 2011 to 2015, a total of 2,050 leading integrated energy efficiency public buildings were selected as "Top Runners" of public energy-consuming entities for demonstration[50]. In 2017, energy consumption of public buildings decreased by 12.9% compared with that in 2010; energy consumption per unit of floor space decreased by 10.2%, and per capita water consumption decreased by 12.6%[51].

50. The definition of energy efficiency "Top-Runners" can be found in the section above on Energy Efficiency in Industry. The Energy Efficiency "Top-Runners" of Public Buildings refer to those public buildings that have had extraordinary performance in meeting energy savings targets, achieving high efficiency in consumption of energy and resources, adopting energy management systems, pursuing system-wide energy savings, conserving water, and pursuing green procurement. China's National Government Offices Administration and the NDRC evaluate the performance of the public institutions.

51. Data source: MOHURD, *13th FYP on Building Energy Efficiency and Green Building Development*, February 2017, available at http://www.mohurd.gov.cn/wjfb/201703/W020170314100832.pdf; Government Offices Administration, *Chinese Public Sector Leading Low Carbon and Green Social Development*, November 2017.

Renewable energy deployment scaling up in buildings

In recent years, more renewable energy has been deployed in buildings with increasing scale, especially in the form of clean heating[52]. Clean heating has been promoted in China's northern area since 2017 and is anticipated to be an important focal area in the future to improve the overall efficiency of building energy use. To cope with air pollution, the National Development and Reform Commission and nine other national government departments jointly issued the *Clean Winter Heating Plan in Northern China (2017-2021) in 2017*. It sets the target that clean heating rate should increase to 50% in the northern area by 2019 and 70% by 2021. In the "2+26" key cities and districts[53], 90% of heating services should use clean energy sources by 2019 and 100% by 2021. At the same time, the Chinese government calls for large-scale renewable energy deployment in clean heating, building energy efficiency to improve, and renewable energy resources to contribute more to clean heating.

Solar thermal energy is a most important component of renewable energy deployment in buildings. By 2016, solar thermal energy contributed 76.6% of renewable energy heating in buildings. China has announced a total of 46 renewable energy building application demonstration cities, 100 demonstration prefectures, and eight solar energy comprehensive utilization demonstration provinces. In urban areas, over 3 billion m² of floor space is using solar thermal energy. From 2006 to 2016, the solar thermal collector area (representative of conventional energy consumption substituted by solar thermal energy) increased at about 17.8% annually on average (Figure 21).

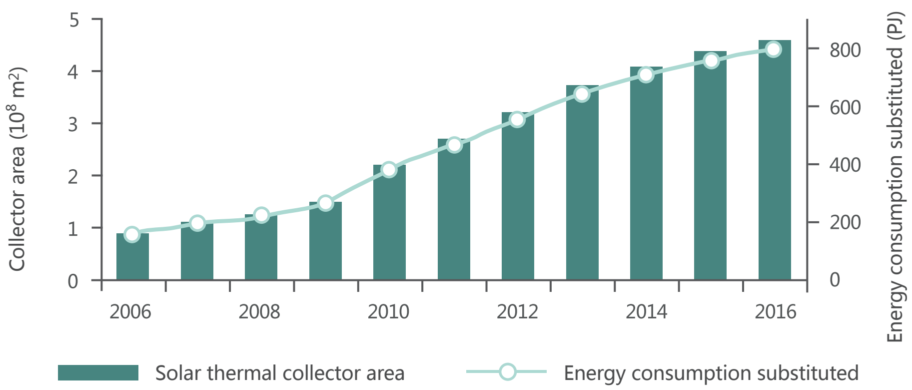


Figure 21 **Solar thermal collector area and energy consumption substitution in China (2006-2016)**
Data source: *China Statistical Yearbooks* & China Solar Thermal Industrial Association.

52. Heating service from clean energy.
53. The "2+26" cities refer to cities located along the pathway through which air pollution in the Beijing-Tianjin-Hebei region transmits. Beijing and Tianjin are the "2", and the "26" include Shijiazhuang, Tangshan, Langfang, Baoding, Cangzhou, Hengshui, Xingtai, and Handan in Hebei Province; Taiyuan, Yangquan, Changzhi, and Jincheng in Shanxi Province; Jinan, Zibo, Jining, Dezhou, Liaocheng, Binzhou, and Heze in Shandong Province; and Zhengzhou, Kaifeng, Anyang, Hebi, Xinxiang, Jiaozuo, and Puyang in Henan Province.

By 2016, geothermal energy accounted for 16.7% of renewable energy heating in buildings, which included direct heating from geothermal water, ground source heat pumps, and water source heat pumps. The Xiong'an New District[54] near Beijing has become an important pilot for geothermal heating. Shallow geothermal energy has been utilized in more than 500 million m^2 of building floor space in China[55]. At the same time, air source heat pumps have also been promoted in the rural areas surrounding Beijing.

Biomass energy also provides heat supply for small- and medium-sized cities to solve the pollution problem caused by scattered use of coal. In 2018, China's National Energy Administration launched a "100 Cities and Towns" demonstration program of biomass combined heat and power generation, where 136 demonstration projects were selected with an anticipated total heating floor space of 90 million m^2 after construction completion[56].

Pilot wind power heating started in Jilin in 2010. Since then, many wind power heating projects have been developed in Sinkiang, Shanxi Province, Inner Mongolia, and other places. A quadrilateral trading mechanism among the government, grid companies, wind farms, and heating suppliers has been established. As of 2016, wind power heated a total building floor space of 5 million m^2 in China[57].

Outlook

Demand for comfort to drive up building energy consumption

Demand for comfortable dwellings in terms of increasing per capita floor space, growing number of energy-using appliances and other equipment, and higher level heating service will continue to drive up building energy consumption in China.

With the improvement of people's living standards, per capita floor space of urban and rural areas in China has increased significantly. With the increase in per capita floor space, urban central heating energy consumption is also on the rise. From 2011 to 2015, per capita floor space of urban areas increased by 11.8 m^2, an increase of 46.1%

54. Located in Baoding City, Hebei Province. Its establishment was announced on April 1, 2017 as the first national-level new special district in China announced by the Central Committee of the Communist Party of China and the State Council. It is also the 19th national new district in China (source: State Council of China).
55. Sources: *China Statistical Yearbook* and New Energy Division of China's National Energy Administration.
56. Source: news from http://www.xinhuanet.com/energy/2018-01/30/c_1122341184.htm.
57. Source: news from http://www.khnuantong.com/news/show-187.html.

(Figure 22). Energy consumption from urban central heating increased from 96 million tce to 120 million tce, an increase of 25% (Figure 23).

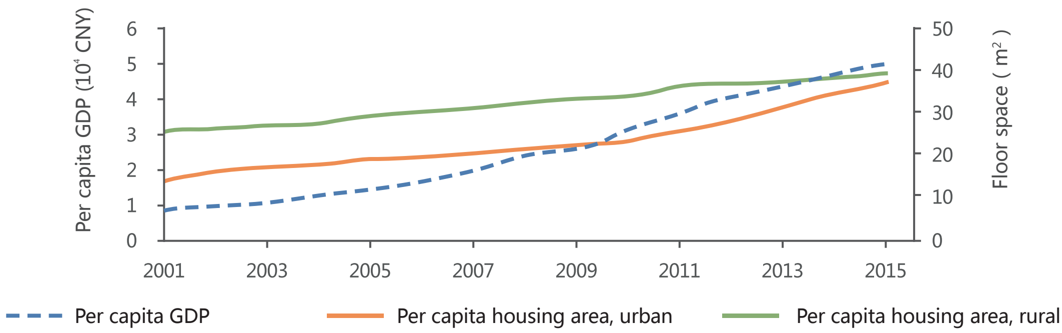


Figure 22 China's per capita housing area and per capita GDP (2001-2015)

Data source: compiled based on *China Statistical Yearbooks*.

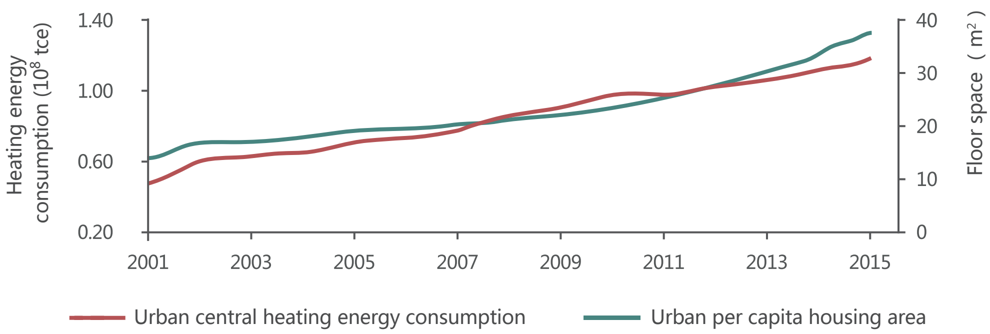


Figure 23 Central heating energy consumption vs. per capita housing area in urban China (2001-2015)

Data source: based on *China Statistical Yearbooks*.

With more frequent extreme weathers (e.g. extremely hot and/or cold weathers) and greater urban heat island effect in recent years, there is an increasingly urgent need to further improve residential living comfort levels in China. In the meanwhile, improved living standards and people's pursuit of better building services have led to the continuous increase of energy-consuming equipment and appliances in buildings. For example, from 2001 to 2017, the number of air conditioners per 100 households increased from 36 to 129 in the urban area, while in the rural area the increase was from 2 to 53 (Figure 24).

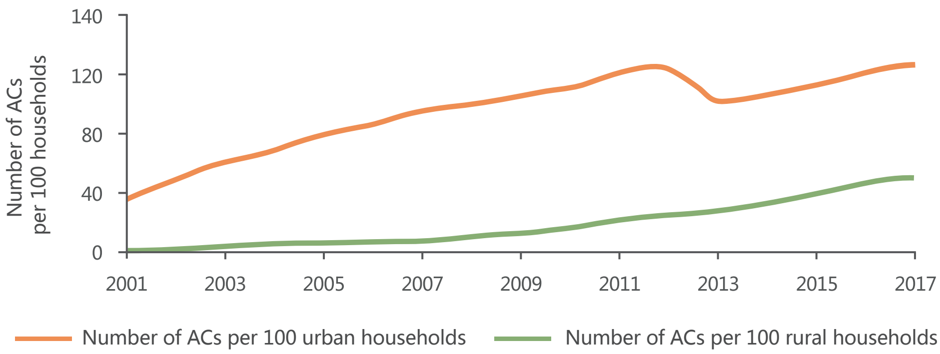


Figure 24 Air conditioner stock per 100 households in urban and rural China (2001-2017)
Data source: based on *China Statistical Yearbooks*

The level of thermal comfort[58] in urban households in northern China is far behind that of developed countries. From 2001 to 2015, energy consumption of central heating in northern China grew at an average annual rate of 6.9% (Figure 19). Heating energy consumption in rural areas of northern China also increased significantly. The average share of heating energy use in the total energy consumption of a single household increased from 31% in 2001 to more than 60% in 2015[59]. In addition, heating demand for buildings in the hot summer and cold winter climatic zone is increasing. Energy consumption for heating will continue to rise in China.

Green buildings and communities to accelerate building energy efficiency transition

In 2015, China revised and implemented the *Green Building Evaluation Standard*. By 2017, 25 provinces have established localized green building standards. Except for Sinkiang, all of these provinces have set up evaluation agencies for green buildings. Shanghai, Tianjin, Jiangsu Province, Hunan Province, Hubei Province, Sichuan Province, Sinkiang, and some other provinces and/or cities have carried out third party evaluation for green buildings. Green building standards have been broadly implemented in government subsidized housing programs at the provincial level and above, government invested welfare buildings, and large public buildings. Provinces and cities including Beijing, Tianjin, Shanghai, Chongqing, Jiangsu Province, Zhejiang Province, and Shandong Province have started implementing green building standards in new buildings. By the end of 2016, a total of 7,235 building projects in China had received Green Building Certification with a total floor space of more than 800 million m^2 (Figure 25). [60]

58. The PMV thermal comfort evaluation indicator was proposed by Danish scholar P. Fanger in the 1970s, which comprehensively takes into consideration six influencing factors including air temperature, relative humidity, average radiant temperature, air flow rate, and others. It is a commonly used indicator for measuring building thermal comfort levels.
59. Data source: collected from multiple MOHURD reviews.
60. Source: collected from multiple announcements by MOHURD, retrieved from http://search.mohurd.gov.cn/?tn=mohurd&lastq=%24wstquerystring%24&sort=last-modified+desc&rn=10&auth_info=&table_id=%24wsttableid%24&pn=0&query=%E7%BB%BF%E8%89%B2%E5%BB%BA%E7%AD%91%E8%AF%84%E4%BB%B7%E6%A0%87%E8%AF%86%E9%A1%B9%E7%9B%AE%20%E5%85%AC%E5%91%8A&ty=a&ukl=&uka=&ukf=&ukt=&sl=&ts=&te=&upg=0.

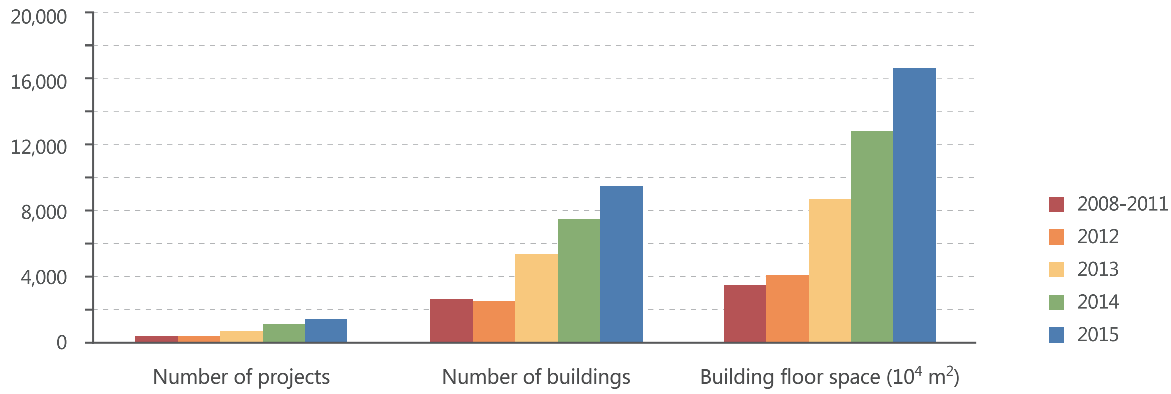


Figure 25 Number of projects, buildings, and floor space with Green Building Certifications in China (2008-2015)

Data source: collected from multiple announcements by MOHURD

According to the MOHURD's *13th Five-Year Plan for Buildings Sector Development* issued in 2017, by 2020: all new urban residential buildings should meet the energy efficiency design standards for new buildings, improving energy efficiency by 20% compared to the 2015 levels; the share of green buildings in new urban buildings should reach 50%, 30% of new construction residential floor space should be fully finished homes[61], green building material application rate should reach 40% in new buildings, and the share of prefabricated building in new construction floor space should reach 15%. In addition to constructing single green buildings, the Chinese buildings sector is also developing new green communities[62] and facilitating the green transition of old communities. 55 new green districts and/or communities have been planned and developed in 12 provincial capital cities, and 200 new districts and/or communities have been constructed in 144 prefecture-level cities in order to promote green development on the regional scale. Beijing, Tianjin, Shenzhen, and other cities have carried out green upgrades and energy efficiency retrofits in old communities or city districts through energy efficiency improvement, seismic strengthening, infrastructure upgrading, and renovation of the community and/or district environment.

Market mechanism to be new impetus for public building energy efficiency

Building energy efficiency improvement, especially by the means that public buildings lead by example, benefit the whole society in addition to the building owners, while not all beneficiaries have to pay for the benefits, causing an unbalanced relationship between costs and benefits. This is known as "positive externality" in economic terms, and the government often weighs in with policies to address the issue, where subsidy is a typical policy for positive

61. Refers to a pre-equipped residence product that improves the overall building energy efficiency throughout its life cycle by optimizing the interior design.
62. Refers to communities that consist of green buildings and sustainable community environment as well as life style.

externality. However, as more public and other buildings become energy efficient, subsidizing efficiency improvement through government investment alone is neither feasible nor good for the healthy development of a self-sustaining building market. Market-oriented mechanisms thus have a huge potential to improve building energy efficiency.

Before 2017, China's first two batches of key public building retrofit cities (11 cities with 24.5 million m^2 of retrofit floor space) were subsidized by the national government at a rate of 20 CNY/m^2 retrofitted. In 2017, the third batch of key public building retrofit cities (29 cities with 69.6 million m^2 of retrofit floor space), assuming the same subsidy rate, would require a subsidy fund totaling about 13 billion CNY at project completion by 2020[63]. If the retrofits and subsidy were to extend to all existing buildings in China (including public and other buildings), assuming the same subsidy rate, it would cost approximately 870 billion CNY of subsidies.

As a matter of fact in 2017, the national government changed its subsidy policy for public building energy efficiency retrofits: the national government decided not to directly subsidize the 29 cities in the third batch of key public building retrofit cities, but to provide financial support for the 4 million m^2 of demonstration public building retrofit projects only. In response, pilot programs of market mechanisms in the field of public building energy efficiency retrofits started. For example, Beijing and Hangzhou have begun to establish diverse financing models for building energy efficiency, with the U.S.-China Green Fund and green bank loans introduced on the basis of cooperation between cities. Building energy efficiency green loan products introduced in Shanghai and Shenzhen not only include traditional financial products in energy efficiency and green development, but also include innovative financing models including green bonds and using future savings or emissions permits as loan security. The *National Plan for New Urbanization (2014-2020)* and *Opinions on Accelerating the Construction of Ecological Civilization* issued by the Chinese government have explicitly promoted various market mechanisms such as public-private partnerships (PPP), energy performance contracting, energy savings trading, and carbon emissions trading. Under continuous government guidance, the private sector will increasingly engage in building energy efficiency improvement. These efforts to introduce and scale up market mechanisms will enable them to become new driving forces in building energy efficiency improvement in China.

63. If following the current retrofits of 15%-20% efficiency improvement, the demand for subsidy fund in 2017 key public building retrofit cities is 13 billion CNY. If deep retrofits (of 50% efficiency improvement) were conducted, the subsidy fund demand would be even greater, totaling 90 billion CNY.

Energy Efficiency in Transportation

Overview

China's transport sector has significant impacts on energy consumption, climate change, and human health. The transport sector consumes over 60% of oil and emits 12% of GHG emissions of the entire economy in China, among which onroad vehicles mainly composed of cars and heavy-duty vehicles represents about 75% of transportation GHG emissions (Figure 26).

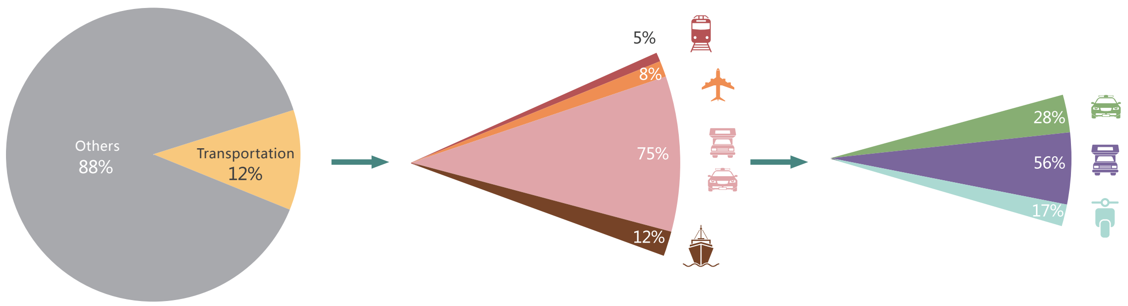


Figure 26 Transport GHG emissions in China (2017)
Source: ICCT Roadmap Model

China remains the world's largest vehicle market and has maintained a record-setting annual average growth rate of 13.3% for new vehicle sales, driven primarily by the rapidly growing passenger car sector, for the entire past decade from 2008 to 2017 (Figure 27). Annual new sales of motor vehicles in 2017 were nearly 28.9 million; three times that of ten years ago. China also has the world's fastest development of battery electric, plug-in hybrid, and fuel cell vehicles, also known as the new energy vehicles or NEVs, over the past five years. In 2017, China produced and sold over 0.77 million electric vehicles, representing more than half of total production and sales around the globe[64].

64. Sources: Announcements of China Association of Automobile Manufacturers and multiple news sources.

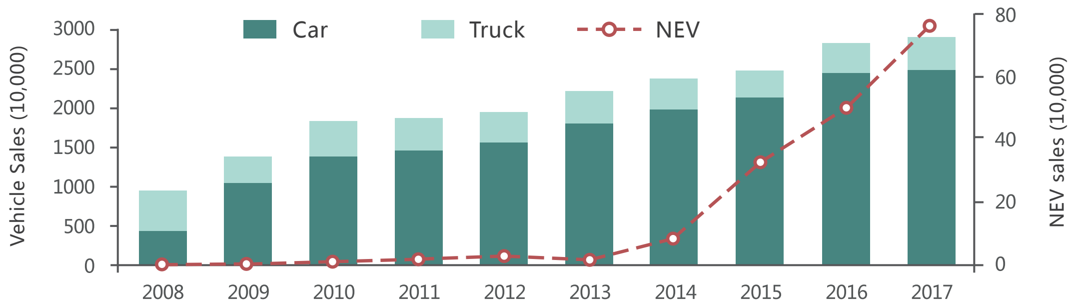


Figure 27 Annual sales of on-road vehicles and NEVs in China (2008-2017)

Data source: compiled from various public sources, mainly from the China Association of Automotive Manufacturers.

Since 2004 China has published a series of energy efficiency standards to regulate new cars and heavy-duty vehicles given the significant impact of energy consumption from road vehicles. Specifically, the Chinese Ministry of Industry and Information Technology (MIIT) introduced the first phase of the fuel consumption standard for passenger cars in 2004 and implemented it in 2005, and consequently tightened the standard in 2008, 2012, and 2016[65]. The latest standard, implemented in 2016, sets a fleet-average fuel consumption target of 5 liters/100 kilometers (L/100 km) in 2020, or about a 28% reduction from the 2015 level.

For heavy-duty vehicles, the first voluntary efficiency standard[66](or Phase I) was published in 2011 and implemented in 2012, after which MIIT issued a national mandatory standard (Phase II) in 2014. In 2018, the regulatory agency released the Phase III standard to further tighten the standard for the overall fleet by about 15% below the 2015 level, which will become effective in 2019. Figure 28 presents a rough timeline of the regulatory development of China's light-and heavy-duty vehicle fuel efficiency standards in the past decade and half (details of the standards will be explained in subsequent sections).

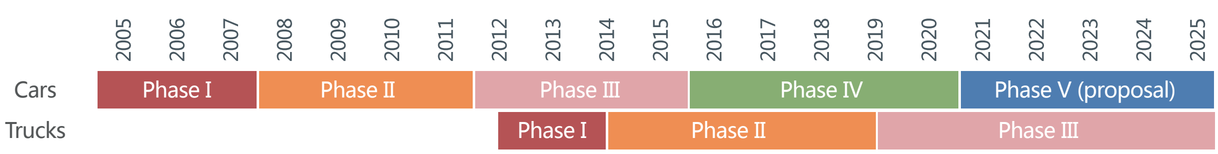


Figure 28 Timeline of car and heavy-duty vehicle efficiency standards

65. The years refer to year Phase II, III, and IV of the standard, respectively.
66. Although this is a recommended standard, it was enforced by MIIT and thus has the same effect as mandatory standards.

Trends and Highlights

Strong and continuous policy pushing for vehicle efficiency

A series of policies and regulations have played a key role in driving the efficiency improvement of cars and trucks in the past decade (Box 3). These measures are pushing China's efficiency requirements for cars to a world-class level, narrowing the gap in heavy commercial vehicle efficiency with developed markets, and nurturing the world's fastest growing electric vehicle market.

Box 3 Recent Transportation Energy Efficiency Policies in China

Adjustment of national government subsidies for new energy vehicles. On January 1, 2017, China implemented an updated subsidy program for battery electric vehicles (BEVs); plug-in hybrid electric vehicles (PHEVs), including extended-range vehicles; and fuel cell vehicles (FCVs). With this round of adjustment, national government subsidies for NEVs will phase down from 2018 to 2020 and completely phase out in 2021..

Issuance and implementation of NEV market entrance requirements. On Jan 6, 2017, MIIT announced the requirements of market entrance of NEV manufacturers and vehicle products, which was implemented in July the same year. The rule specifies a number of safety, efficiency, and vehicle technical requirements for NEVs that are allowed to enter the market.

Release of the *Mid- to Long-term Development Plan for the Automotive Industry* in April 2017. The Plan plots a roadmap for the nation to achieve a high efficiency and low carbon vehicle fleet in the next few years. It sets out specific targets of meeting 5 and 4.5 L/100 km fleet-average fuel consumption for all new passenger cars and fuel-efficient passenger vehicles, respectively, by 2020, and 4L/100 km for new passenger cars by 2025. For heavy-duty commercial vehicles, the Plan aims for the nation's new heavy duty vehicle fleet to match world-class efficiency by 2025.

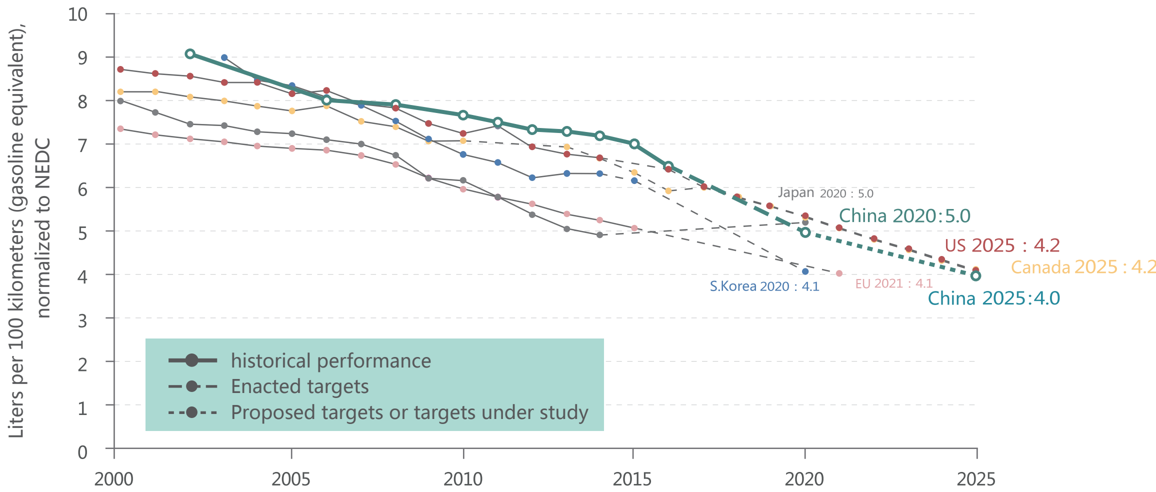
Issuance of corporate-average fuel consumption and new energy vehicle credit system (also known as the "NEV mandate"). In September 2017, China's MIIT and four other ministries finalized a national NEV mandate. The NEV mandate is a modified version of California's Zero Emission Vehicle (ZEV) mandate, with goals of promoting new energy vehicles and providing additional compliance flexibility to the existing fuel consumption regulation. It applies only to passenger cars and formally takes effect on April 1, 2018.

Release and implementation of the Exemption of Vehicle Acquisition Tax for NEVs. In December 2017, the Ministry of Finance and three other ministries announced a fiscal policy to waive the vehicle acquisition tax for NEVs sold between January 2018 and December 2020. New NEV models must meet a series of technical requirements to qualify for this tax incentive. MIIT approves and publishes a list of eligible models periodically.

Release of the Phase III fuel consumption standard for heavy-duty vehicles. In February 2018, MIIT released the final China Phase III fuel consumption standard for heavy-duty vehicles. The rule will take effect in July 2019 and is expected to reduce fleet-wide fuel consumption by about 15% in 2020 below 2015 levels, in order to further reduce the gap between China and other more developed markets globally.

Efficiency standards for passenger cars evolving among world class

China implemented and proposed sets of efficiency standards for new cars that are among the world's most stringent in post 2020 (Figure 29). Notably, the 2020 standard requires over 6% annual improvement in efficiency from 2016 to 2020, and a fleet average fuel consumption level of 5L/100 km in 2020 for the new passenger vehicle fleet, the deepest reduction among the world's ten regulated markets. The proposed 2025 goal of 4L/100 km in the *Mid- to Long-term Development Plan for the Automotive Industry* would put China in the lead position in terms of absolute value in fleet fuel efficiency, over other international community's long-term ambitions.



*Note that Japan has already exceeded its 2020 statutory target,as of 2013.

Figure 29 Historical efficiency performance, current and future standards for new cars in various markets (2000-2025)

Since 2014, MIIT has published annual compliance reports for the Phase III and IV corporate average fuel consumption regulations for new light-duty vehicles. These reports, combined with other sources of historical data, showed consistent reduction of fleet-average fuel consumption from 2004 to the present, which is also reflected in Figure 29. In 2016, the fleet-average fuel consumption of all new passenger cars was about 6.5 L/100 km.

Despite the progress made in fuel efficiency of the new vehicle fleet, a growing amount of evidence has indicated a major gap between type-approved fuel consumption and actual in-use fuel consumption levels [35]. This suggests the need for actions to improve testing protocols and methods to make the test results correctly reflect the in-use fuel consumption performance, ensuring that the in-use fuel consumption performance complies with the standards as tested.

Efficiency standards for trucks narrowing the gap with developed countries

In China, heavy-duty vehicles or HDVs currently represent about 10% of the new vehicle market. However, because of their high fuel consumption and heavy use in terms of vehicle kilometers traveled, HDVs account for nearly 50% of China's total on-road fuel use.

Since 2012, China has adopted three phases of efficiency standards for new heavy-duty vehicles. The standards set maximum fuel consumption limits for various vehicle utility segments such as straight trucks, tractors, city buses, and long-distance coaches. For each segment, the fuel consumption limits are indexed to gross vehicle weight, that is, the heavier a vehicle model the more lenient its standard. The required efficiency improvements associated with each standard vary by segment and are summarized in Table 1 below.

Table 1 Reduction of fuel consumption from Phase I to III HDV efficiency standards by segment

VEHICLE SEGMENT	REQUIRED IMPROVEMENT IN EFFICIENCY		
	FROM PHASE I TO II	FROM PHASE II TO III	FROM PHASE I TO III
Tractor	14%	15.3%	27.2%
Truck	11.5%	13.8%	23.7%
Coach	10.5%	12.5%	21.7%
City Bus	N/A	14.1%	14.1%
Dump Truck	N/A	15.9%	15.9%

China is among the few major vehicle markets that have enacted mandatory efficiency (or GHG) standards for heavy-duty vehicles. The others are the United States, Canada, Japan, and India. Figure 30 compares the relative stringency of these national standards with respect to the baseline defined when the standards were introduced for one common vehicle type across the regions – tractor trucks. The nearly 30% reduction in fuel consumption[67] required from the progressing standards between 2014 and 2020 in China makes it one of the most ambitious

67. The figure shows reduction requirements of CO_2 emissions in various regions, which are representative of fuel consumption reduction requirements.

regulated markets in improving its heavy-duty vehicle fleet efficiency.

Despite China's strong ambition in greening its HDV sector, gaps in terms of technologies and the absolute value of vehicle efficiency still exist between the current Chinese HDV fleet and those in the U.S. and Europe. For example, average fuel consumption for new tractor trucks in China is rated at about 44 L/100 km, compared with 33-36 L/100 km in the U.S. and 31L/100 km in Europe [36]. China lags behind in terms of the market penetration of nearly all engine and vehicle body efficiency technologies such as advanced turbocharging, automatic and dual clutch transmission, aerodynamic technologies, low rolling resistance tires, and energy management. The Phase III standard is expected to help narrow the gap in new HDV fleet fuel consumption between China and advanced markets by about 10%-15% [37].

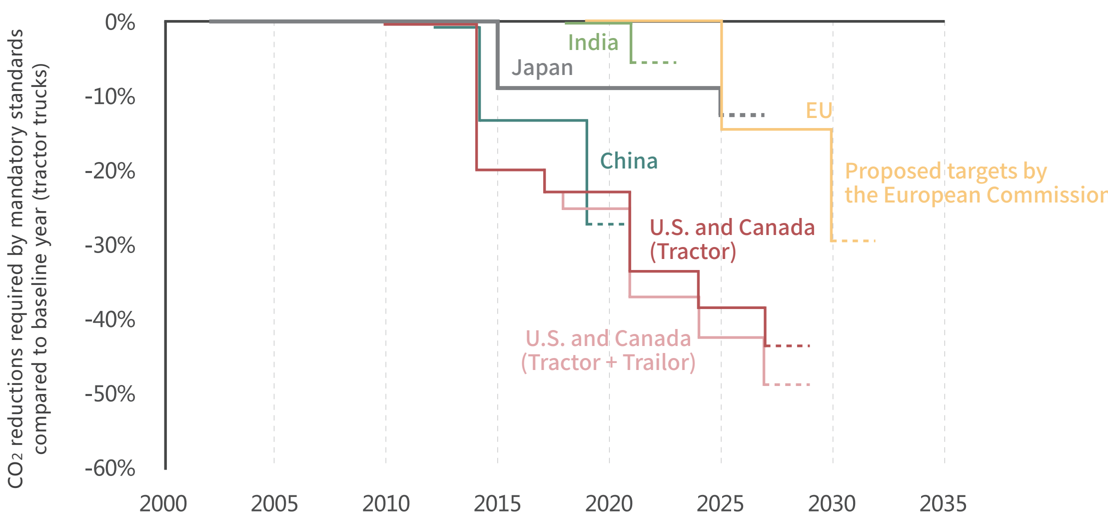


Figure 30 Relative stringency of tractor truck standards around the world (2000-2035)
Source: ICCT policy update report – *The European Union's Proposed CO_2 standards for Heavy-Duty Vehicles.*

China being world's fastest growing market for electric vehicles

Vehicle electrification is part of China's national strategy to upgrade its auto industry and pursue a clean energy development path. Benefiting from the substantial national subsidies and local incentives introduced in the past decade, the NEV market, including pure electric, plug-in hybrid electric and fuel cell vehicles, has witnessed phenomenal growth. With an annual growth rate of at least 50% for four consecutive years, China has emerged as the global leader of electric vehicle production and sales. In 2016, China sold 0.34 million electric passenger cars, or 45% of the world's total. In 2017, NEV sales in China contributed to almost half of the total sales worldwide.[68]

The current Chinese NEV market presents several unique features. First, electric cars have been deployed disproportionally at the subnational level. The top five provincial-level markets – Zhejiang Province, Shanghai, Guangdong Province, Shandong Province, and Beijing – purchased over half of the total electric cars in the nation. The top dozen markets represented 80% of the entire national NEV market (Figure 31). City-level NEV market data revealed that a handful of economically and politically dominant cities, also known as the Tier 1 and Tier 2 cities, deployed the majority of new energy cars. In 2017, average sales of new energy cars in Tier 1 and 2 cities were over 17,000, compared with an average of about 600 in the rest of Chinese cities.[69]

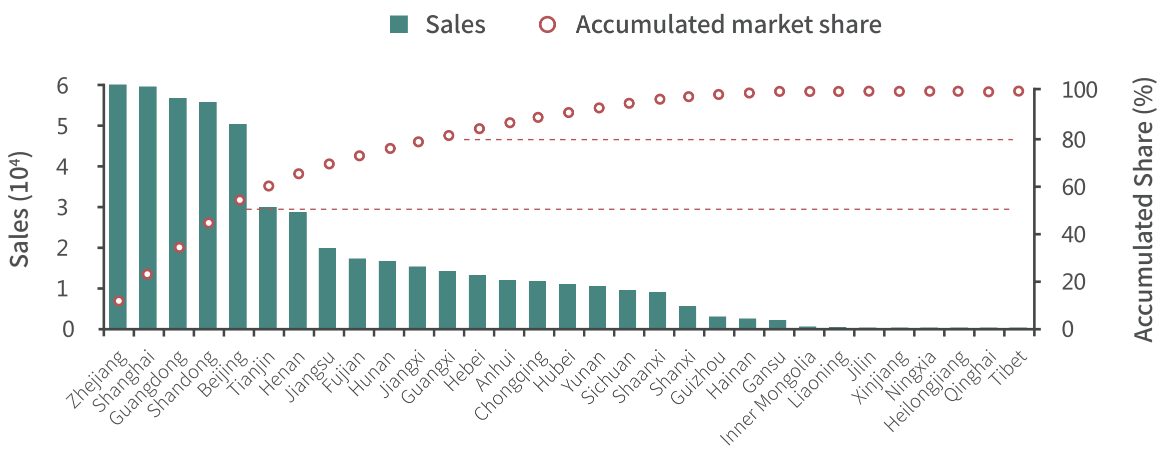


Figure 31 Sales and cumulative market share of electric cars by province (2017)

Source: China Association of Automobile Manufacturers

Second, micro battery-electric cars[70], represented by BAIC EC, Zhidou, Kangdi, and JAC iEV series are dominating the Chinese new energy car market. In 2015 and 2016, micro electric cars made up about 70% of all new battery electric cars [38]. By comparison, top electric car models in the U.S. market were large or luxury models represented by the Tesla Model S and X, followed by the mid-to small-sized Nissan Leaf and VW eGolf in 2016.

68. Sources: Announcements of China Association of Automobile Manufacturers and multiple news sources.
69. Sources: Announcements of China Association of Automobile Manufacturers and multiple news sources.
70. The micro cars refer to two to four seaters with typical wheelbase between 2 and 2.3 meters and are often economy vehicles with average list price ranging between 30,000 and 60,000 CNY.

Green freight emerging from concept to pilot program

Freight transportation is essential to China's economic growth. Heavy-duty trucks, which transport about 80% of total goods, have become the top fuel consuming vehicle segment in China. Heavy diesel trucks also emit a disproportionally large amount of air polluting emissions. Currently, diesel is still the primary fuel used by freight trucks. In 2017, diesel trucks, being less than 4% of total vehicle population, emitted over 3 million tons of nitrogen oxides (NO_x) and nearly 0.4 million tons of primary particulate matter (PM), representing about 57% and 78% of total NO_x and PM emissions from all motor vehicles. [39]

Given the energy and environmental significance of the freight sector, in October 2014, the China State Council released the *Mid- to Long-Term Development Plan for the Logistics Industry (2014-2020).* The target is to build an organized, technologically advanced, convenient, efficient, green, environmentally friendly, and safe and orderly modern logistics industry by 2020. A number of policies and regulations have been introduced surrounding four strategies to improve trucking efficiency and reduce its emissions (Box 4).

On top of the above state and sectoral actions towards building a greener freight industry, local pilot green freight programs and government-industry platforms are also emerging. In 2010 and 2011, the Guangzhou City and Guangdong Province successively implemented green freight demonstration projects involving promotion of vehicle efficiency technologies, drop and hook, logistics information disclosure and sharing, and training of eco-driving to truck owners.

Box 4　Policies and regulations to improve trucking efficiency and reduce its emissions

Improving per-vehicle efficiency and emissions performance: as previously mentioned, the latest Phase III fuel consumption standards for heavy-duty trucks expect to tighten truck efficiency by more than 20% from 2014 to 2019. China also recently announced its Phase VI emissions standard for heavy-duty vehicles, requiring 77% and 67% reduction in NOx and PM emission rates of new trucks starting from 2020. The Ministry of Transportation released a policy in 2017 aiming to drop energy consumption of road truck per freight turnover by 6.8% and decreasing CO_2 emissions from transportation by 7% in 2020 compared with 2015 levels, among other green logistics measures.

Reducing empty drive: in 2009, five national government departments released a joint policy that identifies drop-and-hook as an advanced transport mode and plays an important role in reducing logistics costs, reducing energy consumption and emissions, and improving overall economic development.

Multimodal freight movement: in 2016, 18 national government departments and the China Railway jointly released a policy to promote multimode freight movement, especially the mode of rail-road combination. Starting from 2017, as part of the Blue Sky national campaign, China began to ban the use of truck-based shipments of bulk goods like coal to various ports around the Bohai Sea.

Clean fuel technologies: although the current penetration of zero emission technologies in the freight industry is low (below 1%), rapid transition to electrification is expected to take place in city bus, taxi, and logistics sector according to a recent announcement made by China’s Ministry of Transportation in June.

Outlook

Huge potential to be tapped from internal combustion engine efficiency improvement

China has an immense opportunity to promote energy efficiency for its cars and trucks in the years to come. Despite the multiple standards introduced to date on vehicle efficiency, gaps still exist in the stringency and enforcement of these standards between China and the international best practices.

China needs longer-term (post 2030) standards, to provide manufacturers with clear, consistent signals for long-term investment into truly advanced technologies and to allow for better payback of their investment. Future standards need to be both stringent and technology-neutral to fully mature internal combustion efficiency technologies and help the transition to zero emission technologies. For example, the current China Phase III heavy-duty fuel consumption standard would reduce tractor-trailer fuel consumption by about 3% per year until 2020. After 2020, China could further reduce fuel consumption by 21% by 2025 through commercially available technologies including engine efficiency improvement, low rolling resistance tires, and improved aerodynamics. China could lower HDV fuel use by a total of almost 45% from the 2020 level by also applying in-development technologies that are expected to be commercially available in the 2025–2030 timeframe, such as waste heat recovery, integrated tractor-trailer aerodynamic designs, and hybridized powertrains [40].

Policy makers need to incorporate data-driven research into longer-term technology roadmaps for light- and heavy-duty vehicle efficiency improvement, integrating cost-effectiveness of the existing, emerging, and prospective technologies when determining the stringency of those standards.

In addition to developing new, stringent, long-term standards, it is essential to ensure the in-use compliance of these standards so that real-world energy saving expectations are met. Consumer reports are useful. But more importantly, regulatory agencies would need solid, experimental data for enforcement purposes. There are both domestic and international best practices. Similar approaches in the in-use surveillance procedures required from China's Phase VI vehicle emission regulations, involving manufacturer- and agency-run laboratory and real-road driving emission tests, can also help in-use energy efficiency assurance. Effective in 2012, the U.S. Environmental Protection Agency required an in-use CO_2 emissions requirement in its in-use testing programs[71].

NEV market to transit towards better sustainability and strength

China's *Mid- to Long-term Development Plan for the Automotive Industry* released in 2017 projects that about one out of five newly produced vehicles in China should be powered by new energy by 2025 [41]. Assuming China's auto market continues to grow at the current pace, this will translate to over 7 million new NEVs in 2025, making China a clear global leader in vehicle electrification in the medium term.

The rapid growth in NEV volume, nevertheless, does not necessarily mean China will have a self-sustaining and strong market of electric vehicles in the long run. China is not yet ahead of the curve in key technological developments of electric motor trains. Further, the strong growth trend achieved so far has been heavily relying on the decades-long substantial government stimulus.

China's central government has made its first move toward turning pure financing into a combination of mandatory requirements and various local incentives. In 2017, the central government introduced a mandatory NEV credit program or the NEV mandate. Similar to California's landmark ZEV regulation, China's NEV credit program mandates manufacturers to meet the NEV credit requirement[72], which is 10% and 12% of their annual production volume of conventional-fuel passenger cars in 2019 and 2020, respectively. Depending on the technology mix of the future fleet, the program can lead to up to 12% of NEVs among all new passenger cars in 2020.

Although the NEV mandate can create a strong top-down push for NEV market growth, ultimately, a sustainable NEV market will rely on strong and continuous consumer demand as well. Consumers and fleets in cities will be

71. Source: U.S. Environmental Protection Agency.
72. The NEV credit of a manufacturer = credit for NEV Model 1 * volume of NEV Model 1 + credit for NEV Model 2 * volume of NEV Model 2 + ... + credit for NEV Model n * volume of NEV Model n. If the NEV credit is not lower than the credit requirement, the manufacturer complies with the program.

increasingly important in deploying a significant amount of newly produced NEVs. Driven by severe air pollution, cities like Beijing and Shanghai see vehicle electrification as a critical strategy for improving local air quality and have adopted aggressive measures to promote NEV deployment, including direct fiscal incentives for NEV purchasing, operating and parking as well as non-fiscal incentives such as license plate and road access privileges for NEV owners and providing convenient public charging infrastructure.

Still, much needs to be done to help with the transition of China's NEV market from large to strong. Experiences from pioneer NEV deployment cities need to be replicated to the vast majority of smaller and polluted cities to help with their NEV market uptake. Technical requirements in safety, efficiency, and performance need to be tightened to ensure continuous advancement and innovation of the NEV technologies. Applications of electrification need to be expanded and extended from light- to heavier-duty transportation sectors, and from urban to non-urban uses, to achieve deeper cuts in energy consumption and pollutant emissions. And finally, intelligent connected vehicle technologies, in combination with zero-emissions vehicle technologies, hold much promise for enabling cleaner and more efficient e-mobility. Multiple technical standards and policies are under development to support these emerging trends [42].

Synergy to increase among efficiency, environment, and climate change mitigation

Clean transportation involves multiple regulatory bodies and economic sectors. Compared with a decade ago, transport-related regulations and government departments today have shown increased coordination to achieve multiple energy and environmental purposes. One example is the recently published China Phase VI emission standards for heavy-duty vehicles, which began to require the monitoring and reporting of CO_2 emissions (which directly relate to fuel efficiency) test results together with those of ambient air pollutants. This new requirement increases the "communication" between HDV fuel efficiency and emissions regulations and prohibits manufacturers from using two sets of calibrations to pass the different regulatory tests, and therefore helps ensure both emissions and fuel economy performance of vehicles in real-world driving conditions.

Stringent vehicle PM emission requirements, like those set by the China Phase VI emission standards, also lead to nontrivial benefits for climate change mitigation since diesel particle filters enforced by the particulate matter standard remove 99% of black carbon-a strong short-lived global warming pollutant. Such trends will become more evident over time. Ultimately, clean transportation can only be realized with synergetic improvement in clean upstream energy, clean manufacturing, and the spread of zero emission vehicle technologies.

3. Energy Efficiency Investment & Financing and Energy Efficiency Market

Energy Efficiency Investment and Financing

Overview

From 2006 to 2016[73], the cumulative investment in energy efficiency[74] in China reached 3.2 trillion CNY [43][44], with the compound average growth rate (CAGR)[75] of 44.1%. This amount of investment accounted for nearly 1% of China's total fixed asset investment during this period. The investment has provided strong financial support for China in its transition to an energy-efficient and low carbon economy. In the past ten years, directed by the government's financial incentives, the influx of private investment and financing has become an indispensable driving force for accelerating China's investment in low-carbon development including energy efficiency improvement, and has played a critical role in achieving the country's energy conservation and emissions reduction targets.

In 2016, China's total investment in energy efficiency was 334.6 billion CNY [45], which was 38.6 times that of 2006. In 2016, the investment by the national and local governments in energy efficiency was 62.8 billion CNY [46], accounting for 18.8% of the total investment in energy efficiency in China; investment from private sector in 2016 reached 271.8 billion CNY. The leverage ratio of public funding in 2016 was 1:4.3.

Private investment in energy efficiency in 2016 was comprised of corporate self capital investment (86.0 billion CNY, or 25.7% of the total energy efficiency investment), energy efficiency loan increment (122.3 billion CNY, or 36.6% of the total investment) as well as other sources of investment such as green bonds, green asset securitization, private equity financing, and green stocks (16.4 billion CNY, 17.2 billion CNY, 8.2 billion CNY and 21.7 billion CNY, respectively) (Figure 32).

73. The latest available data on energy efficiency investment and financing is through 2016. This is applicable in the entire section of Energy Efficiency Investment and Financing.
74. In terms of source of funds, energy efficiency investment in China is divided into government funding and private investment. In terms of use of fund, it is divided into energy efficiency project investment and funding for energy efficiency capacity building.
75. The compound average growth rate (CAGR) refers to the average annual growth rate over a certain time period, CAGR=(current value/base value)^(1/N) – 1; N is the number of years.

Energy efficiency investment covers investment in both energy efficiency projects and capacity building. In 2016, the direct project investment was 333.9 billion CNY, accounting for 99.8% of the total investment while capacity building investment was 720 million CNY (Figure 32).

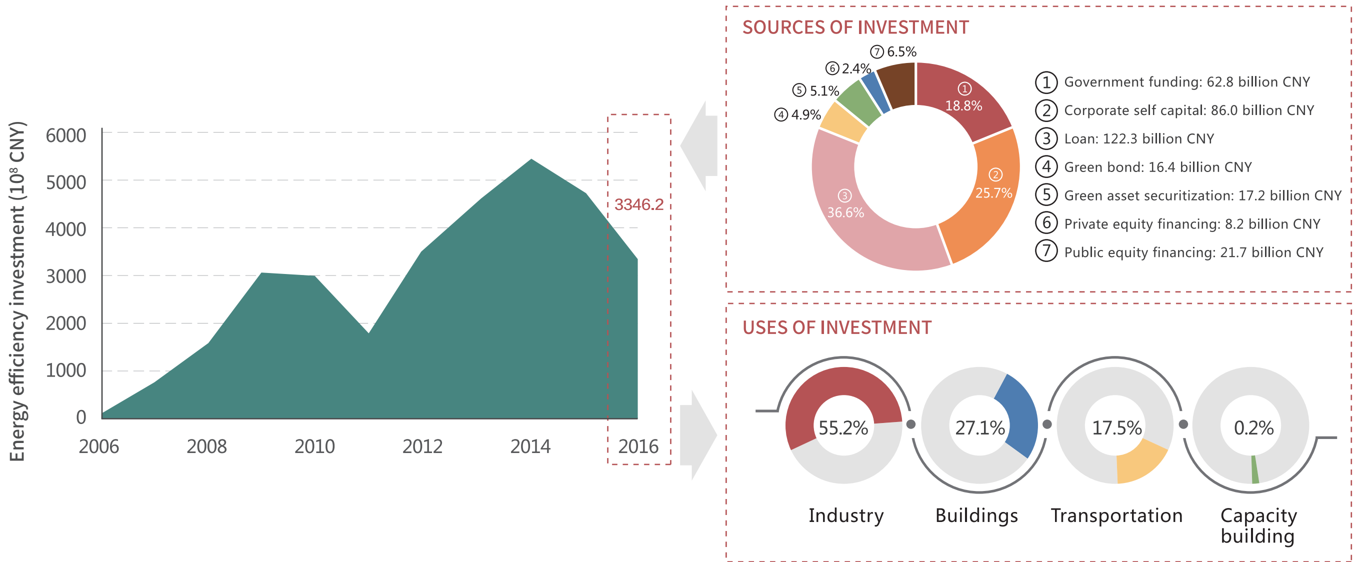


Figure 32 Energy efficiency total investment in China (2006-2016) [76]

Data sources: China Energy Research Society's Energy Efficiency and Investment Evaluation Professional Committee, *China Energy Efficiency Investment Progress Report 2015*; information compiled based on China's national and local government financial statements in 2016 and data from the China Banking Regulatory Commission, international financial institutions, Zero2IPO Data, Wind Data, etc.

Trends and Highlights

Energy efficiency investment increasing in buildings and transportation sectors

In 2016, the share of energy efficiency investment in the industry sector accounted for 55.2% of China's total energy efficiency investment. Despite a slight decrease in the share compared with the average level from 2011 to 2015, the industry sector is still the dominant sector attracting energy efficiency investment. Meanwhile, the shares of energy efficiency investment in the buildings and transportation sectors both saw increases, at 0.2

76. The green financial bonds are debts issued by financial institutions to support the investment of green industries. It is an important component of green bonds. However, because green financial bonds are often issued for loan purposes, when financial institutions report data, the green financial bonds are usually included in loan statistics. Therefore, to avoid double counting, the green bond data shown in Figure 32 does not include green financial bonds.

percentage point and 3.0 percentage points, respectively, compared with the average levels in the 2011-2015 period (Figure 33). The cumulative energy savings resulting from the investments over these years in the buildings and transportation sectors was 6.3 million tce and 5.9 million tce, respectively. In the foreseeable future, with the rise of a new round of technology advancement, as well as the acceleration of urbanization and green development, the shares of energy efficiency investment in the buildings and transportation sectors will continue to increase.

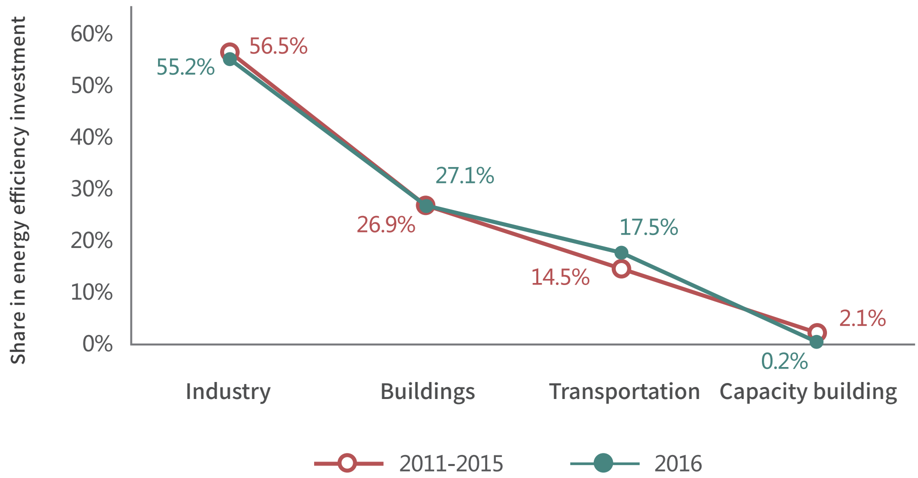


Figure 33 Shares of energy efficiency investment by sector (2011-2016)

Data sources: NDRC, MIIT, MOHURD, Ministry of Transportation; data compiled from China Banking Regulatory Commission, international financial institutions, Zero2IPO Data, and Wind Data.

Energy efficiency fiscal policies enhancing effectiveness of government funding

From 2006 to 2016, China's cumulative energy efficiency investment from government funding totaled 524.6 billion CNY [47], with an average annual growth rate of 31.8%. Effective fiscal support has played a significant role in promoting energy efficiency investment in China (Figure 34). In 2016 alone, energy efficiency investment from government funding in China reached 62.8 billion CNY and its share in total energy efficiency investment increased by 2.7 percentage points from the average level during the 2006-2015 period (Figure 35). Energy efficiency fiscal policies adopted in China have improved the effectiveness of government funding to the country's energy efficiency progress, helping to sustain long-term energy efficiency investment.

Comprehensive	June 2011	Ministry of Finance (MOF) and NDRC incentive fund for energy savings and emission reduction demonstration program
	June 2011	MOF, MOHURD, and NDRC financial incentives for demonstration pilots of green low carbon towns
	July 2011	NDRC support fund from national government budget for resource conservation and environmental protection
	May 2015	MOF subsidy for energy savings and emissions reductions
Industry	May 2012	MOF and MIIT special fund for deep integration of information technology and industrialization
	July 2012	MOF and NDRC national government financial incentive fund for DSM pilot cities
	June 2016	MOF and MIIT measures for managing funding for industrial transformationand upgrading (Made in China 2025 strategy)
Buildings	October 2007	MOF and MOHURD special fund for energy efficiency improvement of national government office buildings and large public buildings
	January 2011	MOF and MOHURD, incentive fund for heating metering and energy efficiency retrofits of existing buildings in northern China
	April 2012	MOF and MOHURD subsidy/incentive fund for green building and green ecological urban districts
Transportation	August 2012	MOF and China Administration of Aviation special fund for energy savings and emissions reduction in the aviation sector
	November 2014	MOF, Ministry of Transportation (MOT), and Ministry of Commerce, subsidizing local government to compensate for vehicle purchase tax revenue
	May 2015	MOF, MIIT, and MOT, subsidy for fuel prices for urban public transport vehicles
	October 2015	MOF and State Administration of Taxation waiver of vehicle purchase taxes for passenger vehicles of 1.6L or smaller
	January 2016	MOF, Ministry of Science and Technology (MOST), MIIT, and NDRC incentive fund for construction of NEV charging stations
	December 2016	MOF, MOST, MIIT, and NDRC subsidy for promoting NEVs

Figure 34 China's in-effect fiscal policies for promoting energy efficiency (published 2007-2016)

Data source: multiple policy documents from NDRC, Ministry of Finance, MIIT, MOHURD, Ministry of Science and Technology, Ministry of Transportation, and other national government departments.

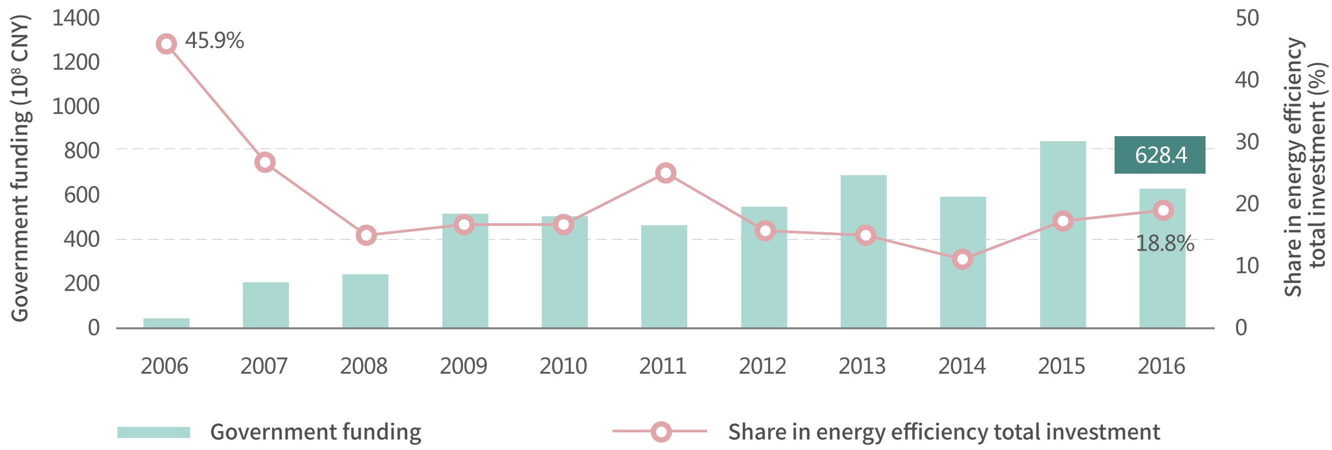


Figure 35 Government funding in energy efficiency and its share in energy efficiency total investment (2006-2016)

Data source: compiled from 2006-2016 national and local government fiscal spending final statements.

Loan financing being major source of energy efficiency investment

Energy conservation and efficiency improvement have become an important part of China's green and low carbon development. As the primary player in China's economic system, Chinese banks are guided by financial reforms that require financial institutions to introduce innovative loan financing products and develop effective risk management strategies to finance energy efficiency improvement. As a result, loan financing in China has been maintained at a high level.

In 2016, energy efficiency loan financing in China by 21 major Chinese banks and some international financial institutions reached 122.3 billion CNY, about twice the amount in 2007 (Figure 36). Over the last decade, energy efficiency loan financing accounted, on average, for about 52% of China's total energy efficiency investment. Chinese policy banks, commercial banks, and other financial institutions have occupied a dominant position in the allocation of financial resources. International financial institutions have also played an active role in China. Overall, loan financing is the major source of energy efficiency investment in China.

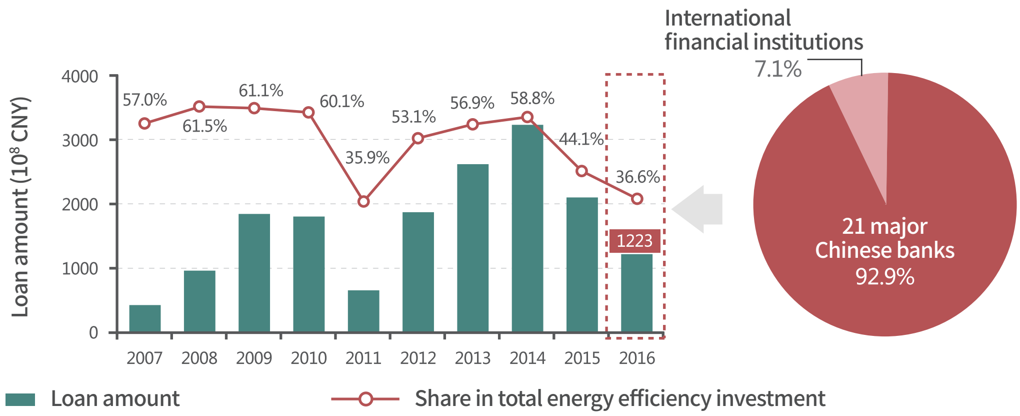


Figure 36 Energy efficiency loan financing from banking institutions (2007-2016)

Source: compiled from documents from the China Banking & Insurance Regulatory Commission, the China Banking Association, the World Bank, Asian Development Bank, KfW, European Investment Bank, and other international financial institutions.

Green bonds and assets securitization broadening energy efficiency Investment

Development of green bonds[77] and green asset securitization[78] to meet the growing needs for investment in the green economy have become evident in China. In 2016, energy efficiency investment raised through green bonds reached 32.9 billion CNY with issuance of 28 green bond products, in which the financial bonds accounted for about 50% while non-financial bonds including debenture, corporate bonds, medium-term notes, etc. accounted for 41.9% (Figure 37).

In 2016, China issued 24 asset securitization products, with a total amount of 17.2 billion CNY, to support energy efficiency improvement, all of which were enterprise asset securitization products. In addition to corporate debt assets and accounts receivable-based underlying assets, there are other asset types including those relying upon revenue rights such as heating charging rights, grid electricity charging rights, and public transport NEV operational income rights (Figure 38).

77. The types of green bonds issued in China include financial bonds, debenture, corporate bonds, mid-term notes, and bonds issued by government agencies.

78. China's asset securitization products mainly include credit asset-backed securities (credit ABS), corporate asset-backed securities (enterprise ABS), and asset-backed notes (ABN) overseen by the China's National Association of Financial Market Institutional Investors.

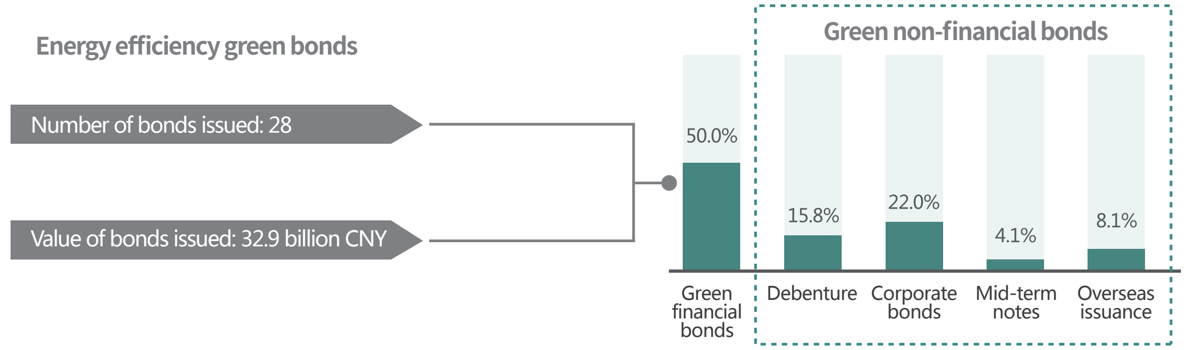


Figure 37 Green bonds for energy efficiency (2016)

Data sources: compiled from Wind Data, China Financial Information Network information, and other data sources.

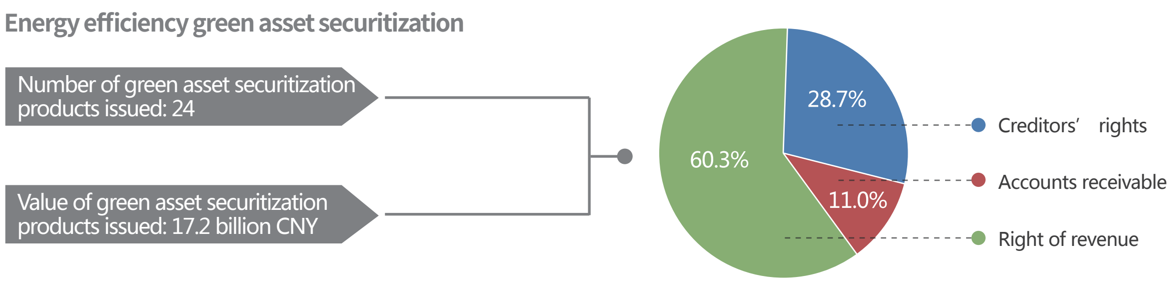


Figure 38 Green bonds for energy efficiency (2016)

Data sources: Wind Data

Private equity funds favoring energy efficiency improvement

In China, energy efficiency has increasingly become attractive to private equity and venture capital funds. Stimulated by new issues of stocks and expedited approval process, China's private equity market has entered a new round of growth, and it is clear that the volume of new funds has become larger. In 2016, there were 87 energy efficiency investment cases in China involving private equity, with a revealed amount of approximately 8.2 billion CNY, about eight times the average annual amount in the period of 2011-2015. In cases where amounts were revealed, most target companies were growth companies, with investments flowing in typically in their expansion and mature phases (Figure 39).

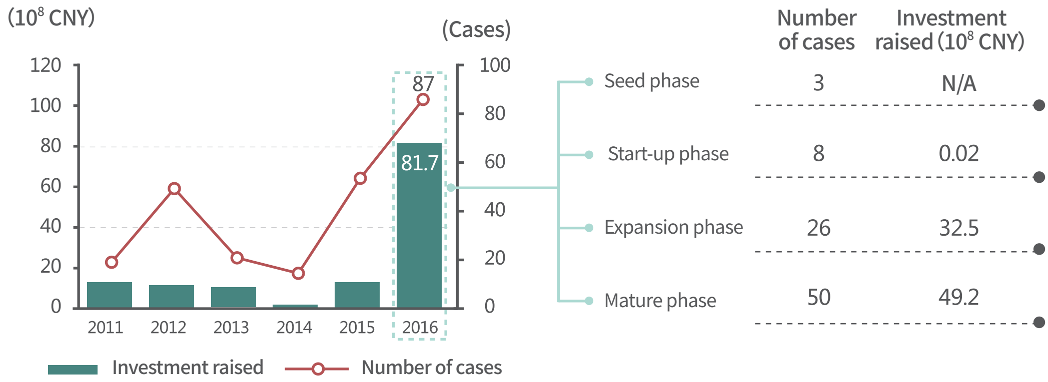


Figure 39 Private equity investment in energy efficiency: number of cases and investment raised (2011-2016)

Source: compiled from Qing Ke Data.

Outlook

Energy efficiency investment demand to maintain its level

China is currently in a critical period for achieving both the 2020 carbon intensity target and its *Paris Agreement* goal to peak emissions around 2030 while striving to peak earlier. Based on past work in energy efficiency improvement carried out during the 2006-2015 period and the energy saving estimates of key energy conservation programs such as adoption of new technologies, elimination of backward production capacity, and capacity building that China will carry out in the near future, China needs to invest nearly 2 trillion CNY between 2016 and 2020 in order to meet the its emissions reduction goals, which is 2.3 times the energy efficiency investment from 2006 to 2010 and roughly the same as the energy efficiency investment from 2011 to 2015 (Figure 40).

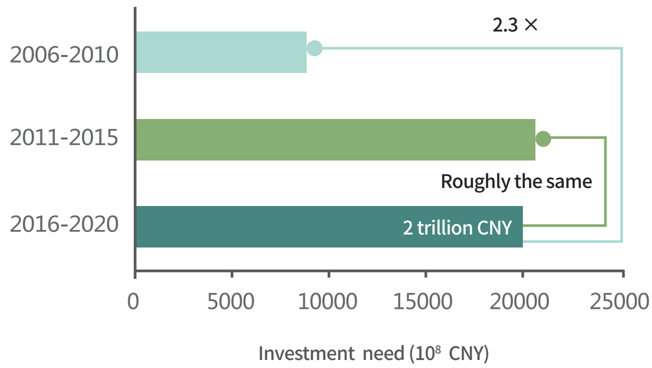


Figure 40 Predicted need for energy efficiency investment (2016-2020)

Energy efficiency investment to diversify

The rapid expansion of green finance has been a highlight of China's financial sector in recent years. With the strong support of the government and active participation of financial institutions, green finance is shifting from exploratory and small-scale applications to a more systematic and large-scale deployment. In pursuit of green finance, China is developing a whole new green financial service system that covers green financing policy, green financial product design and services, risk control, and green standards certification.

Moving forward, energy efficiency project developers in China will not only rely upon commercial loans, but also actively pursue other types of financing such as corporate bonds, medium-term notes, and short-term financial products in order to meet their capital needs in different terms; and they will do so under the premise of effective risk control. New financing products that combine debt and equity investment as well as loan-bond bundling[79] are expected to attract institutional investors such as insurance companies and investment funds to provide long-term investment in energy efficiency. In addition, China will explore more diversified investment vehicles such as energy efficiency asset securitization and leasing financing.

Energy efficiency investment to move towards cross-sector integration

With the on-going changes in the modes of energy production and consumption, advancement in technology, and innovation in financial institutions, energy efficiency investment will innovate beyond traditional investment models and build a comprehensive, one-stop, cross-sector investment system (Figure 41). In fact, energy efficiency technologies are breaking through the boundaries of traditional industries and further extending to sectors other than industry, buildings, and transportation such as agriculture, water conservation, warehousing, and environmental protection. The cross-sector integration of investment helps energy efficiency penetrate the whole economy. At the same time, a comprehensive energy efficiency investment system will handle all aspects of investment including financial markets, policies, services and products, financing mechanisms, risk control, and so on. In the future, the integration of energy efficiency investment will reduce energy efficiency transaction costs, improve the efficiency of investment, accelerate the growth of energy service industry, and promote the sustainable development of the Chinese economy.

79. Refers to the program through which banks develop systematic financing plans for businesses based on their project financial needs and include both corporate bonds and commercial loans in the banks' comprehensive credit management systems to manage the debts of enterprises and their projects in an integrated way.

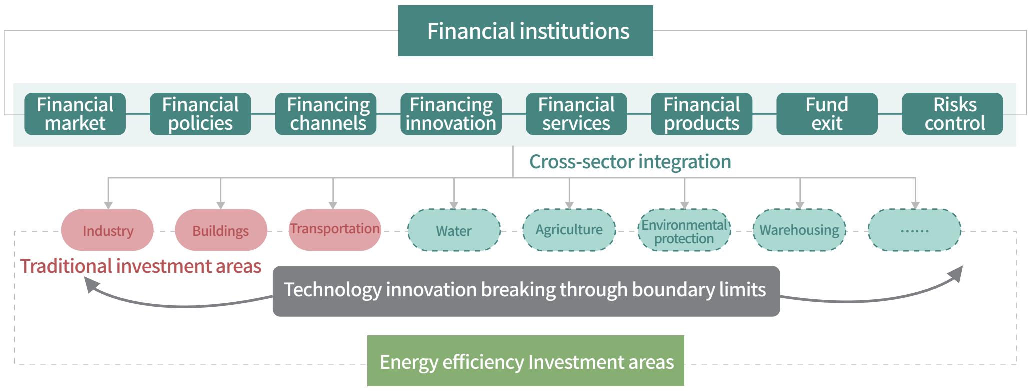


Figure 41 An integrated and comprehensive cross-sector energy efficiency investment model

Energy Efficiency Market

Providing energy saving services by energy service companies or ESCOs[80] through energy performance contracts (EPCs)[81] is an important business model and part of the energy efficiency market. This section focuses on the development of the ESCO market in China (also referred to as "energy efficiency market").

Overview

In the mid-to-late 1990s, the energy performance contracting or EPC mechanism was introduced to China through the China Energy Conservation Promotion Project implemented by the Chinese government in cooperation with the GEF/World Bank (WB). Over the past 20 years after the introduction of EPC and with a strong support from the government, the number of ESCOs has grown significantly and the ESCO industry has developed rapidly. China's ESCO market has been the largest in the world in terms of market value (i.e. project investment) since 2014. In 2017, China had more than 6,000 professional ESCOs with nearly 700,000 employees; the gross output value of the country's ESCO industry was 414.8 billion CNY. In the same year, EPC project investment in China was 111.3 billion CNY, accounting for over 60% of the global total [14] and resulting in 38.1 million tce of

80. An energy service company is a professional service company that provides a wide range of services including energy use diagnostics, energy saving project planning, financing, implementing retrofits (i.e. construction, equipment installation, and commissioning), and operational management among others.
81. Energy performance contracting is a service mechanism in which an ESCO and an energy user enter into a contractual agreement to realize an agreeable amount of energy savings; the ESCO provides services to the energy user according to the contract in order to meet the agreed energy savings target; and the energy user in return makes payment from its achieved energy savings benefits to the ESCO. Energy performance contracting is called Energy Savings Performance Contract (ESPC) outside China (e.g., in the U.S.).

energy savings capacity and more than 100 million tons of CO_2 emissions reduction (Figure 42). It is estimated that by 2020, the gross output value of China's ESCO industry would exceed 600 billion CNY, surpassing the energy savings target set in the *National Energy Conservation Action Plan in the 13th FYP Period*.[82]

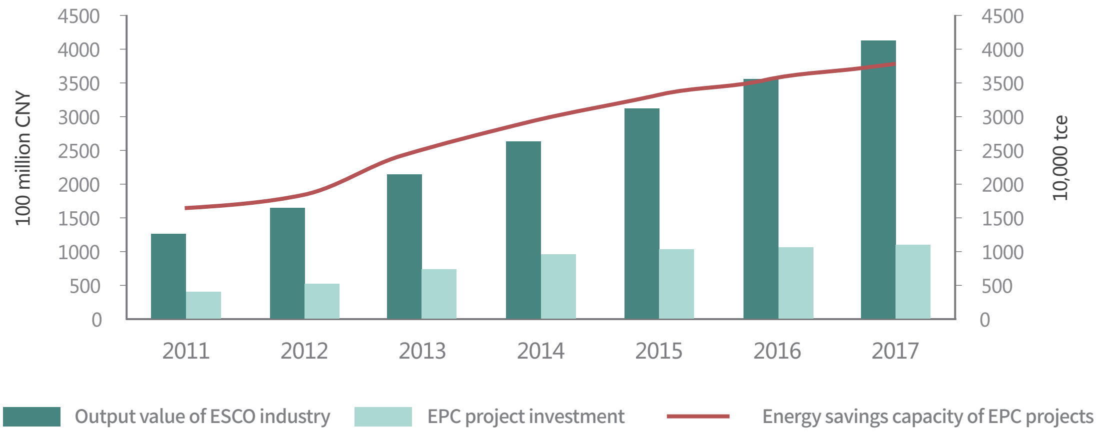


Figure 42 ESCO industry and EPC projects in China (2011-2017)
Date source: the ESCO Committee of China Energy Conservation Association

China's ESCO industry has maintained good momentum over the last two decades due to that fact that China has great energy efficiency potential, along with the favorable policy environment created by the national and local governments. In 2010, China's State Council issued the *Opinions on Accelerating the Implementation of Energy Performance Contracting to Promote the Development of ESCO Industry*, which established the role of the ESCO industry in accelerating economic transition and promoting energy efficiency and emissions reduction. The Chinese government also provided substantial support for the ESCO industry, including financial incentives, tax credits, favorable accounting mechanism, and so on. These incentives gave full play to the role of government funding in leveraging private investment, which together attracted many enterprises into the ESCO market and rapidly scaled up the industry. The development of China's ESCO industry has not only reduced the use of fossil energy, but also improved the efficiency of energy use. It has also played a positive role in stimulating domestic demand for products and services, boosting employment, and expanding the national economy.

82. Data source: the ESCO Committee of China Energy Conservation Association.

Trends and Highlights

Comprehensive energy services changing the ESCO industry

Comprehensive energy services refer to energy services in multiple forms and various processes with integrated solutions to optimize efficiency gains and cost savings. Such services, often provided through chauffage contracts[83], bundle energy system design and planning, energy efficiency financing, project construction, and system operations. Comprehensive energy services could effectively link different types of energy including traditional fossil fuels, new energy, and renewable energy from the supply side and the consumption of water, heat, and electricity from the demand side to meet various needs of end users. Comprehensive energy services change the ESCO industry from the vertical development within the industry chain to the horizontal interconnection across industries, and from the service mode centered on products and technologies alone to more customer side-oriented services. Chinese ESCOs are still in the early stages of providing comprehensive energy services, but with broad prospects.

In recent years, Chinese EPCs have started to shift towards offering systematic and long-term operations and maintenance services as well as expanding from end-use retrofits to supply-side options, and from retrofitting auxiliary equipment to upgrading production process. Under this change, services provided by Chinese ESCOs now cover energy efficiency in energy management and control systems, heat supply systems (i.e. hot water and steam), waste heat and excess pressure utilization, central air conditioning systems, electric motor systems, energy system optimization, energy station construction and operation, energy storage technologies (power storage/heat storage), road/tunnel green lighting, and so on. With the support of incentive policies for new and renewable energy, China's ESCOs have developed a large number of EPC projects on distributed PV and biomass systems. In addition, China is undergoing power market reform aimed at developing competitive wholesale and retail markets, creating great opportunities to provide bundled services for selling electricity and other energy-related services. There are currently 12,000 registered companies in China that sell electricity. According to the ESCO Committee of China Energy Conservation Association (EMCA), 18.7% of China's ESCOs have already involved in sales of electricity and an additional 29.3% are planning to sell electricity.[84]

With the rapid rise of comprehensive energy services, the service scope will be extended, service depth expanded, and energy savings potential further tapped. Given the inborn nature of ESCOs and the fact that Chinese ESCOs are

83. One of EPC contract models; see Box 5 for details.
84. Data source: the ESCO Committee of China Energy Conservation Association.

familiar with the market in China, they have the inherent advantage of becoming comprehensive energy service providers. However, increasing use of smart technology and the growing market demand for advanced know-how have put forward high standards for ESCOs, enabling only the best to survive. While ESCOs are transforming themselves into comprehensive energy service providers, power suppliers and grid companies are also actively pursuing to provide comprehensive energy services. As professional service companies, ESCOs have the opportunity to cooperate with mid- to large-size companies to exploit extra space for their business and market. Moving forward, regardless whether ESCOs themselves become comprehensive energy service providers or technology suppliers that provide only specific services for comprehensive energy service providers, the mainstream service model for future EPC projects are likely to be comprehensive and integrated.

Project sector becoming diversified with buildings projects emerging

China's ESCO market has long been dominated by industrial projects. In the past few years, however, as many energy-intensive industries were facing a weak market, overcapacity, and more stringent environmental and energy requirements, ESCOs have been paying more attention to projects with more stable returns being less affected by economic cycles, such as buildings and infrastructure projects (e.g., clean heating).

In 2015, the NDRC and the MOHURD issued a number of policies to promote residential heating retrofits, which opened up the opportunity for ESCOs to use EPCs to enter the field of clean heating. According to EMCA, 44.8% of ESCOs in China have implemented EPC projects related to heating (hot water/steam), which have good returns, stable revenue, and long-term operations contracts.[85] With the increasing heating demand in southern China, clean heating will be one of the most promising project sectors for ESCOs in the next few years.

Contract models developing in better balance with chauffage increasing

Over the past 20 years after the introduction of EPC in China, energy performance contracting has undergone a series of localization and innovations. The choice of EPC contract models has gradually changed from dominant shared savings model to a balanced mix of all contract models including shared savings, guaranteed savings, chauffage, and financial leasing (Box 5).

85. Source: EMCA.

Box 5 Typical EPC contract models

Shared savings	The ESCO invests in the project.The project host and ESCO share the benefits from energy savings.
Guaranteed savings	The project host invests in the project. The ESCO guarantees the level or amount of energy savings and receives payments from the project host during the contracted period for the guaranteed services.
Chauffage	During the contract period, the project host entrusts the ESCO to fund project construction and to carry out retrofits and operations. According to an agreement of both parties, the operations of the energy system are managed by the ESCO during the contract period and the energy cost savings belong to the ESCO.
Financial leasing	During the contract period, the financing company invests in the ESCO's equipment and services, and leases it to the project host, and charges the host for a leasing fee per the agreement.

Sources: U.S.-China EPC market opportunity analysis white paper.

As the only contract model that was fiscally supported by the Chinese government during the 12th FYP period, the shared savings contract model used to be the mainstream in China. However, with the scaling down of national government incentives for EPC, the share of investment for shared savings in total EPC investment has gradually declined from the average of 70% during 2011-2015 to about 60% in 2017. In contrast, investment for chauffage has grown at a faster rate and demonstrated a strong development momentum. Compared with shared savings, chauffage contracts have much longer contract terms, bring steady revenue, reduce disputes over savings measurement, and enhance customer loyalty. Since 2017, a number of chauffage projects have been implemented in both public and commercial buildings such as hospitals, universities, and hotels.

Promotion of EPCs in the public sector in China has some barriers including lack of interest, lack of EPC-friendly budgeting rules, and obstacles posed by the government procurement and bidding system. The implementation of *Government Accounting Rules* and issuance of guiding documents by China's National Government Offices Administration will facilitate the expansion of EPCs in the public sector. It is expected that the investment in public sector EPCs will see a significant increase in the next three years, and chauffage will more likely become the most attractive contract model for the public sector to carry out EPC projects.

Financial vehicles getting flexible and innovative with financing cost decreasing

The development of the ESCO industry requires large investment, and only deep involvement of the financial industry can make the ESCO industry sustainable. After 2010, under strong and direct governmental financial and tax support, China's ESCO industry has gone through a leap development. International organizations including the World Bank, the International Finance Corporation (IFC), the Asian Development Bank (ADB), and the French Development Agency (AFD) all have played important roles in helping China develop an effective financing structure and system to support the ESCO market growth. Through green re-lending, risk sharing, and capacity building, these international organizations have cooperated with Chinese domestic banks such as the Shanghai Pudong Development Bank, Bank of Beijing, Hua Xia Bank, Industrial Bank, and so on to strengthen their capabilities in developing innovative financial products for ESCOs and identifying and mitigating potential risks. Box 6 shows selected examples of support from international organizations and innovative financing vehicles of China's domestic financial institutions in creating effective financing support to help with the development of China's ESCO market.

Box 6 Support from international organizations and innovative financing vehicles of China' s financial institutions

Domestic financing innovations under support from international organizations

In 2017, with the support of the WB, China's Hua Xia Bank launched the Financing Innovation for Improving Beijing-Tianjin-Hebei Air Quality program. A large number of ESCOs that conduct EPCs in iron and steel production and power generation have received WB low-interest loans re-lent by Hua Xia.

With support of the ADB, China National Investment & Guaranty Corporation (I&G) officially launched the Beijing-Tianjin-Hebei Regional Air Pollution Prevention and Control Financing Support program. I&G utilized ADB's low-interest loans and comprehensive financial instruments to establish a green financial platform, which is currently used to finance projects of energy conservation, emissions reduction, clean energy promotion, waste energy utilization, and green transportation.

Diversified financing products by Chinese financial institutions

Green bonds: through the issuance of green bonds in 2017, China's Shanghai Pudong Development Bank, Industrial Bank, and Bank of Beijing obtained a total of nearly 100 billion CNY for green development projects including EPCs in energy efficiency.

Green Asset Securitization: a number of domestic banks and leasing companies have accepted the franchise rights provided by ESCOs as a collateral when issuing loans for green transportation, central heating, and other energy saving projects, and explored using account receivables for green asset securitization products.

Insurance products: there are insurance companies and insurance brokers working with banks to explore relevant insurance products to mitigate potential risks of payment default and/or under-performance of EPC projects.

Future direction for innovation in green financing in China

Single financing models may no longer be able to meet the investment needs of ESCOs and diversified EPCs. To deepen the linkage between the ESCO industry and capital, China has created the first eco-fund that makes the energy efficiency as a priority investment field. The fund will facilitate collaborations among traditional financial institutions with equity investment and mezzanine investment to attract more non-public capital to create tailored and flexible financial solutions for the China' s ESCO industry.

Sources: EMCA

According to EMCA, financing for EPC projects in 2017 exceeded 70 billion CNY. Loan financing from Chinese banks is the largest source of financing, accounting for 41% of the total; financial leasing and equity financing have shown upward trends compared with past years (Figure 43). In particular through equity financing, some ESCOs that acquire advanced technologies have obtained investments from publicly listed companies or state-owned enterprises, which helped accelerate their business expansion. In terms of financing cost, over half of externally financed investments enjoyed annualized financing costs (i.e. interest rates) below 10%, a slight decrease from the past. This is largely due to the fact that after years of business operations, many ESCOs have established relatively mature business models, which have been recognized by financial institutions, thus improving their own credit standing.

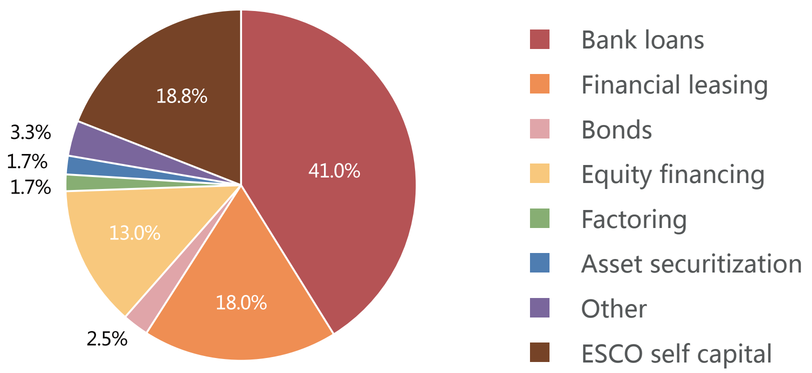


Figure 43 ESCOs' funding sources and corresponding shares (2017)

Source: EMCA

Outlook

Stricter energy and environmental policies to offer new opportunities for ESCOs

In recent years, the Chinese government has issued more and tougher energy and environmental regulations to curb pollution and restructure industries. Through the promulgation of a series of environmental policies such as the *Environmental Protection Planning for the 13th FYP Period*, the creation of the ecological protection red lines, the Blue Sky national air quality campaign, and establishment of environmental surveillance, China's energy conservation and emissions reduction work have moved towards pragmatic implementation. Some non-compliant enterprises have been forced to close. Energy-intensive industries such as iron and steel, chemicals, building materials, and non-ferrous metals, as well as emission-intensive cities, are under great pressure to make significant improvement. Although China has made remarkable progress, the country needs to step up its effort in order to achieve the 2020 and longer-term environmental quality improvement and energy efficiency goals. However, targeting end-of-pipe solutions to meet long-term environmental and energy goals is not only costly, but also constrained by technology.

In contrast, energy efficiency improvement can provide a solution that addresses the problems from its source, thus reducing the use of polluting fossil fuels while lowering energy costs. Undoubtedly, tougher environmental and energy regulations will create tremendous market opportunities for ESCOs. For example, a number of ESCOs have seized the opportunity created by tougher regulations to reduce NO_X emissions in Beijing, Tianjin, and Xi'an among other cities, to retrofit industrial boilers, replace equipment, and install smart combustion control solutions to minimize the amount of NO_X generated.

In addition, the Chinese government has put in place the "double control" policy to control both energy consumption and intensity. The policy breaks the national target of energy consumption into the provincial targets and allocates the targets to sectors as well. This requires implementation of major energy efficiency and environmental protection programs. Further, to more effectively cut carbon emissions, the Chinese government officially launched a national carbon trading market in 2017, which at the current stage caps only emissions from the power generation sector. The energy and emission caps will increase operational costs of enterprises and create intrinsic motivation for energy users to either conserve energy or improve energy efficiency. This will no doubt create abundant opportunities for ESCOs to expand their EPC business.

ESCOs to merge into large comprehensive companies and ESCO industry to upgrade

The average asset value of ESCOs has increased from 30 million CNY in 2013 to 67.6 million CNY in 2017. 1/4 of EPC projects have achieved an annual energy saving capacity exceeding 10,000 tce. Although the ESCO industry is growing one year after another, 90% of the 6,000 ESCOs in China are still small- to medium-sized enterprises (SMEs), all facing limitations in service scope, technologies, capital, and creditworthiness.[86]

On one hand, large ESCOs such as power suppliers and grid companies entering the market would squeeze the market available for SMEs. For SMEs, only by strengthening innovation, improving core competitiveness, focusing on market segmentation, and developing differentiation strategies can they survive.

On the other hand, with increasing comprehensive energy services, EPCs are changing from isolated, single-facility projects to large-scale, integrated projects for industrial parks, communities, and even cities. Competitive advantages are increasingly determined by capital and technologies, which will pose higher standards for large ESCOs to have technical strength, financing capability, service quality, and risk control among other competitiveness. China's ESCO industry will continue its consolidation and integration in the next three to five years. A smaller number of leading large ESCOs with technological advantages and economic scales will dominate the ESCO industry.

Participation of publicly listed companies that take advantage of their own technologies, market share, and financial resources in the ESCO market will greatly boost the overall scale of the industry. Therefore, these publicly listed companies will become some of the most competitive players in China's ESCO market. As of 2017, there were 151 listed companies with business in energy conservation and environmental protection. 60 of them conduct EPC projects. These 60 ESCOs had revenue total of 912 billion CNY with a net profit of 68.5 billion CNY in 2017. Their EPC business included clean heating, district energy services, distributed energy, LED lighting, waste heat utilization, and building energy efficiency solutions, with district energy services and distributed energy being strong growth areas. According to rough estimates, 15 of the above-mentioned 60 listed ESCOs have set up ESCO subsidiaries as equipment manufacturers and suppliers to use EPC in installing energy saving equipment, or conduct equipment & service integrated business, to create high profits for the parent companies[87]. In addition to

86. Source: EMCA.
87. Source: China Galaxy Securities.

establishing affiliated ESCOs, publicly listed companies also expand their EPC business through horizontal or vertical merges and acquisitions. Such measures will not only help to maintain their business growth but also realize unique advantages of the acquired enterprises to strengthen their own competitiveness and capture more and greater market opportunities.

4. Conclusions and Recommendations

The signing of the *UN Framework Convention on Climate Change* (UNFCCC) in 1992 started the international joint effort of addressing global climate change. After some twists and turns, the *Paris Agreement* brought the world to an unprecedented consensus to achieve ambitious climate goals. As the "first fuel", energy efficiency is both a key solution to achieving the climate goals and a critical driving force for sustainable economic prosperity. China has experienced serious environmental, energy, and climate change problems resulting from its rapid economic growth. Starting from the enactment of the country's Energy Conservation Law in 1998, China has prioritized energy efficiency as one of its most important government agendas.

China has established an energy conservation management system implemented by governments at both the national and local levels to implement relevant policies and programs. Following the implementation of the *Energy Conservation Law*, the Chinese government put forward a series of comprehensive and specific and/or sectoral energy efficiency policies. Since 2006, the Chinese government has been paying greater attention to emissions reduction and efforts to combine emissions reduction and energy savings. The policies took into consideration the shared global interests and created a policy environment conducive to energy efficiency improvement both nationwide and in specific fields. Stimulated by strong policy support and financial incentives, the private sector has been playing a large part in energy efficiency promotion with significant private investment in energy efficiency. Meanwhile, China is taking an active part in international collaborations on energy efficiency improvements, sharing its own experience and best practices with other countries and bringing more countries into the ally to address climate change.

Over the last decade, China has made significant progress from its efforts. The country's overall energy intensity decreased nearly 40% between 1998 and 2017. The energy efficiency improvement also lowered the growth in energy consumption; the growth rate of dropped 10.5 percentage points between 2005 and 2017. China achieved all these with an average GDP growth rate of 9% between 2005 and 2017.[88]

88. Source: Data source: *China Statistics Yearbooks* and *China Energy Statistics Yearbooks*.

The industry sector is a primary contributor to both economic growth and energy consumption in China. After going through economic reform, industrial structure changes, and phase-out of outdated capacity, industrial energy intensity has decreased and the growth rates of energy consumption in heavy industries have been declining. The industry sector continues to be a major venue for energy efficiency improvement in China. In the buildings sector, China is expected to continue rapid urbanization until 2030. As a result, the total floor space, building energy intensity, and total building energy consumption are going to increase in the near and medium term. During this growth period, it will be a challenge for China to meet its citizens' growing demand for more and better services that will consume more energy in buildings, yet to also avoid excessive energy and resource use. China has taken serious measures such as developing energy efficiency standards for new buildings, conducting energy retrofits in existing buildings, and promoting energy efficiency improvement in the public sector. In addition, renewable energy is being increasingly deployed in Chinese buildings. In terms of the transportation sector, China is the world's largest market for on-road motor vehicles, and is expected have freight demand grow by five to six times by 2050. The Chinese government has implemented a set of energy efficiency standards and policies on LDVs and HDVs since 2005. These standards and policies, together with the world's highest sales of electric vehicles, will ensure the high-quality and high-efficiency development of the Chinese transportation sector.

In the past ten years, stimulated by the government's financial incentives, the influx of private investment has become an indispensable driving force for accelerating China's low-carbon development including energy efficiency improvement, and has played a critical role in achieving the country's energy savings and emissions reduction targets. Ever since the introduction of EPC in China in the 1990s, the ESCO industry has been developing rapidly, and the size of the Chinese ESCO market has been the largest in the world since 2014. The ESCO industry has been providing energy services for industrial facilities, commercial and public buildings, and public infrastructure.

There is a great potential for energy efficiency improvement in China yet to be captured. We offer the following recommendations that could help the country further improve its energy efficiency and seize the opportunities:

- **Continue improving energy efficiency standards by raising minimum standards and establishing top performer standards.**

  Minimum standards could improve the average energy efficiency of the market by increasing the lower bound, while top performer standards push up the upper bound by recognizing best performances in energy efficiency and encouraging the rest of the society to adapt. With the two kinds of standards functioning together, overall energy efficiency could be improved.

- **Reinforce the implementation of energy efficiency policies to ensure effectiveness.**

  For a specific policy, it is common that the implementation may not be as effective as designed at the very beginning when it rolls out. Only through using the implementation results as feedbacks and the basis for adjustment can policies become more effective.

- **Actively promote R&D, commercialization, and deployment of energy efficiency technologies.**

  The energy savings capacity of existing technologies is limited; and only technology innovation and breakthrough can capture further efficiency improvement opportunities. Technology advancement is also the foundation for developing an efficient and high-quality economy in China. In addition, it is critical for China to develop polices, financial support, and implementation strategies for effective technology commercialization and deployment to quickly bring technologies to the marketplace.

- **Facilitate technology integration, project coordination, and comprehensive services.**

  Energy efficiency projects are becoming more and more integrated, coordinated and comprehensive, seen in the industry, buildings, and transportation sectors. Only through integrated technologies and solutions can ESCOs better adapt to the tendency of project coordination and merge, forming comprehensive systems and functioning way better than isolated solutions.

- **Engage the private sector.**

  Government financial incentives could foster greater energy savings and efficiency improvements in the initial stages; however, in the long term China needs a cost-effective and self-sustaining system to support large-scale energy efficiency deployment. For this, the private sector plays an irreplaceable role. On one hand, in areas where policies already have had effects, government incentives are phasing out (if not already). External financing introduced at this time could help support continuous and healthy development of the market. On the other hand, enterprises are important targets for energy efficiency improvement. It is thus critical to make them recognize that energy efficiency can help enhance their competiveness for long-term growth and motivate them to improve energy efficiency spontaneously.

- **Maintain active participation in international cooperation on energy efficiency.**
  The exchange of information on energy efficiency policies and technologies, the sharing of thoughts and ideas, and the dissemination and learning of best practices are the “sources of living water” that help China address energy, environmental, and climate change challenges. China’s achievements in energy efficiency improvement and its contribution to global climate change mitigation are unquestionable, yet China still needs to keep enriching itself and making progress through continuous international cooperation and exchange.

Having in mind China’s energy efficiency progress to date, we look forward to its even better performance with consistent efforts in energy efficiency improvement and climate change mitigation.

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List of acronyms, abbreviations, and units of measure

AC	air conditioning
ADB	Asian Development Bank
AFD	French Development Agency
AQSIQ	General Administration of Quality Supervision, Inspection, and Quarantine
BBC	British Broadcasting Corporation
BEV	battery electric vehicle
BRICS	Brazil, Russia, India, China, and South Africa
CAGR	compound average growth rate
CEM	Clean Energy Ministerial
CNY	Chinese yuan (Chinese currency)
CO_2	carbon dioxide
COP	Conference of the Parties to UNFCCC (or UN Climate Change Conference)
DSM	demand-side management
ECW	Energy Conservation Week
EELP	(G20) Energy Efficiency Leading Program
EE values	energy efficiency standard values
EMCA	ESCO Committee of China Energy Conservation Association
EnMS	energy management system
EPC	energy performance contracting
EPCs	energy performance contracts
ESCO	energy service company
EU	European Union
FCV	fuel cell vehicle
FYP	five-year plan
G20	Group of Twenty
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
HDV	heavy-duty vehicle
IEA	International Energy Agency

IFC	International Finance Corporation
km	kilometer
kWh	kilowatt hour
L	Liter
LDV	light-duty vehicle
LED	light-emitting diode
m^2	square meter
MIIT	Ministry of Industry and Information Technology
MOF	Ministry of Finance
MOHURD	Ministry of Housing and Urban-Rural Development
MOST	Ministry of Science and Technology
MOT	Ministry of Transportation
NDC	nationally determined contribution
NDRC	National Development and Reform Commission
NEV	new energy vehicle
NEV mandate	corporate-average fuel consumption and new energy vehicle credit system
NOx	Nitrogen Oxides
NPC	National People's Congress
OECD	Organization for Economic Cooperation and Development
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
PPP	public-private partnership
SME	small and medium-sized enterprise
SSE	Shanghai Stock Exchange
tce	ton(s) of standard coal equivalent
UN	United Nations
UNFCCC	UN Framework Convention on Climate Change
U.S.	United States
WB	World Bank
ZEV	zero emission vehicle

ANNEX: Energy Efficiency Milestones in China in 2017

Comprehensive Industry Building Transportation Financing & Market

2017.01

- MOF and three other ministries issued *Adjusting the Financial Subsidies for the Promotion of New Energy Vehicles.*
- MIIT released *Administrative Rules on Market Entrance of New Energy Vehicle Manufacturers and Products.*

2017.02

- NDRC announced the *G20 Energy Efficiency Leading Plan.*
- State Council released *Promoting the Sustainable and Heathy Development of the Buildings Sector.*
- NDRC and MOHURD issued *Notice on Launching Pilot Work for Developing Climate-Adapted City.*

2017.03

- MIIT released *2017 Key Work Plan for Industrial Energy Conservation Monitoring.*
- MOHURD released *the 13th Five-Year Plan on Building Energy Efficiency and Green Building Development.*
- MOHURD released *Action Plan for Prefabricated Buildings in the 13th Five-Year Plan Period, Management Rules on Prefabricated Building Demonstration Cities*, and *Management Rules on Creating Prefabricated Building Industrial Bases.*
- National Energy Administration issued *Opinions on Deepening Reforms of Energy Sector Investment and Financing Systems.*
- People's Bank of China and four other ministries released the *Guidelines of Providing Financial Support to Chinese Manufacturing Industry.*
- China Securities Regulatory Commission issued *Guiding Opinions on Supporting Development of Green Bond.*

2017.04

- MIIT published the *Notice on the Implementation of the 2017 Recommended Industrial Energy Savings Technologies and Equipment and Evaluation of the "Energy Efficiency Star" Products.*
- MOHURD released the *13th Five-Year Plan for Buildings Sector Development.*
- MIIT, NDRC, and MOST issued the *Mid- to Long-term Development Plan for the Automotive Industry.*
- MITT and China Development Bank published the *Notice of Recommending Industrial Energy Efficiency and Green Development Key Loan Programs in 2017.*

2017.05

- NDRC issued the *Notice of Carrying out Voluntary Energy Savings Commitment Program.*
- General Administration of Quality Supervision, Inspection, and Quarantine (AQSIQ) and NDRC released the *Guiding Opinions on Further Strengthening Energy-Related Measurement Work.*
- MOF and three other ministries announced the *Notice on National Government Fiscal Support of Clean Winter Heating Pilots in Northern China.*

2017.06

- CEM 8 convened in Beijing with Initiatives and campaigns announced.
- MOHURD and China Banking and Insurance Regulatory Commission published the *Notice of Improving Public Building Energy Efficiency in Key Cities.*
- State Council Executive Meeting decided to establish Green Financing Reform Experimental Zones in certain provinces.
- State Council released the *Plan of Developing Financial Industry Standardization System (2016-2020).*
- Shanghai Stock Exchange (SSE) and China Securities Index Co., Ltd. issued the SSE Green Corporate Bond Index, SSE Green Bond Index, and China Securities Exchange Green Bond Index.

2017.07

- G20 Summit in Hamburg, Germany kicked off the *G20 Hamburg Climate and Energy Action Plan.*
- Anhui Province announced China's first local-level green and ecological indicators system in urban-rural development.

2017.08

- Ministry of Foreign Affairs issued the *Progress Report on China's Implementation of the 2030 Agenda for Sustainable Development.*
- NPC amended the *Tendering and Bidding Law* and the *Regulations on the Implementation of the Tendering and Bidding Law.*

2017.09

- NDRC and AQSIQ issued the *Work Plan for the Promotion and Development of Online Energy Savings Monitoring System for Key Energy-consuming Organizations.*
- MOHURD and three other ministries issued the *Guiding Opinions on Promoting Clean Heating in Urban Areas in Northern China.*
- NDRC released the *Policy Opinions on Clean Heating Pricing in Northern China.*
- MIIT and four other ministries released the *Parallel Management Approach of Vehicles Average Fuel Consumption and New Energy Vehicle Credit System for Passenger Car Manufacturers* (i.e. NEV mandate).
- SSE officially joined the United Nations Sustainable Securities Exchange Initiative.
- MOF and four other ministries published the *Notice on Issuance of Enterprise Income Tax Concessions for Special Equipment for Energy Conservation, Water Conservation, and Environmental Protection (2017 Edition).*

2017.10

- The 19th National Congress of the Communist Party of China decided to promote green development and establish a sound economic system for green and low carbon circular development.
- The 8th U.S.-China Energy Efficiency Forum was held in the United States.
- People's Bank of China issued the *Registration Regulation on the Pledge of Accounts Receivable.*

2017.11

- The energy efficiency side event was held in China Pavilion of COP 23 in Bonn, Germany.
- NDRC issued the *Notice on Implementation of the "Hundred, Thousand, and Ten Thousand" Action of Key Energy Users.*
- State Council issued *Guiding Opinions on Deepening "Internet +" Advanced Manufacturing and Developing Industrial Internet.*
- MIIT, NDRC, and AQSIQ issued the *Notice on Organizing the 2017 Selection of Energy Efficiency Top Runners from High Energy-consuming Industries.*
- MOHURD released the list of the first batch of prefabricated building demonstration cities and industrial bases.
- MOHURD and China Banking Regulatory Commission issued the *Notice on Approving the Plan for Energy Efficiency Improvement of Public Buildings in Key Cities in 2017.*
- NDRC issued the *Guiding Opinions on Encouraging Participation of Private Capital in Public-Private Partnership (PPP) Projects.*

2017.12

- NDRC approved the implementation plans of Zhejiang, Henan, Fujian and Sichuan provinces for developing energy-use rights trading schemes.
- NDRC released the *National Carbon Emission Trading Market Development Plan (Power Generation Sector).*
- MOHURD published the *Notice on Further Standardizing the Management of Green Building Evaluation.*
- NDRC and nine other ministries announced the *Clean Winter Heating Plan in Northern China (2017-2021).*
- MOF and three other ministries released the *Announcement of New Energy Vehicle Purchase Tax Waiver.*
- People's Bank of China and China Securities Regulatory Commission issued the *Interim Guidelines for Evaluating and Certifying Green Bonds.*