European Futures for Energy Efficiency

649342 EUFORIE

Energy Efficiency Policies and Measures in China

WP8 Deliverable D8.1

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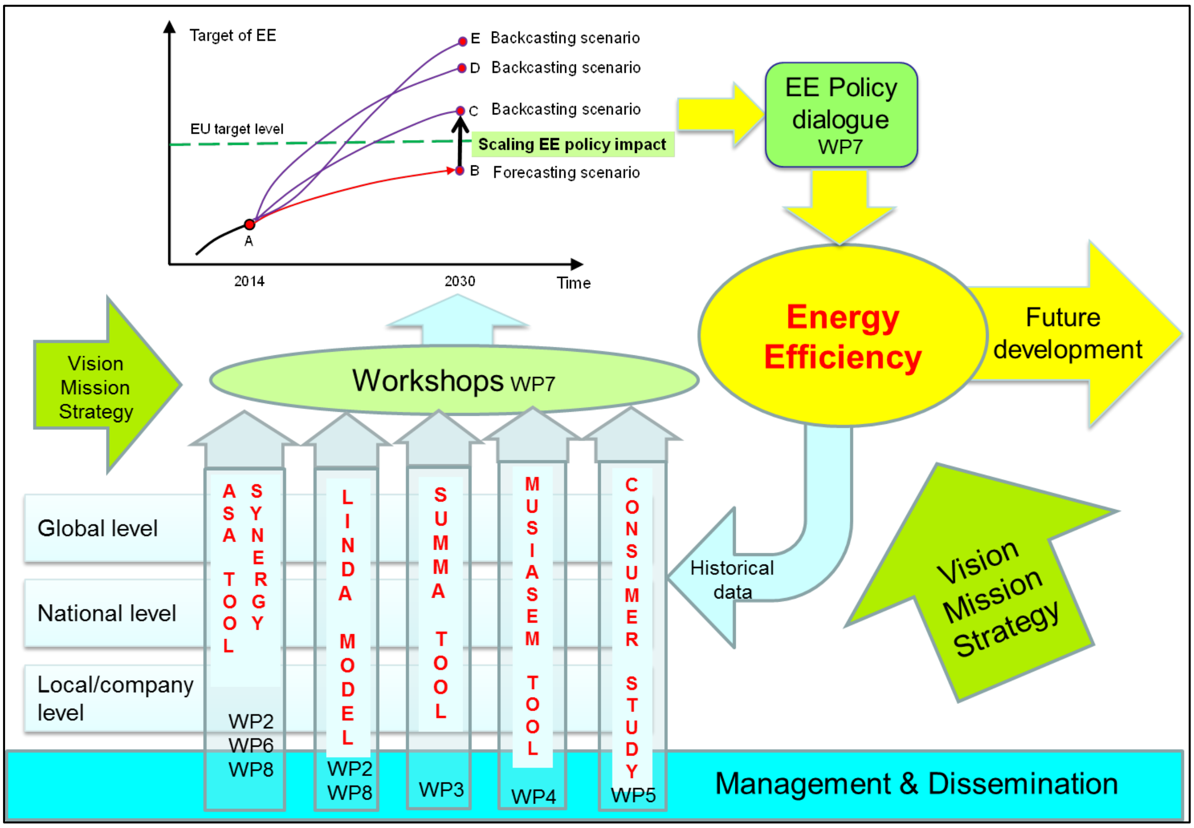
The EUFORIE project

The strategic goal of the EUFORIE project is to provide useful and accurate information and knowledge in the field of energy efficiency for the EU Commission and stakeholders in the Member States. The tangible objectives are the following:

1. To provide energy and energy efficiency trends and their drivers, synergies and trade-offs between energy efficiency related policies, as well as energy efficiency scenarios (WP2).
2. To provide data about implementation of energy efficiency in specific processes, sectors and entire systems, in order to understand bottlenecks/efficiency drops and suggest improvements (WP3).
3. To carry out analyses of efficiency of provision, from making useful energy carriers from primary energy sources, and from conversion of energy carriers to end uses across macro-economic sectors (WP4).
4. To identify policy instruments and other measures leading to significant reduction in the energy consumption of households (WP5).
5. To analyse the relationship between investments and change in energy efficiency, and to develop indicators to describe changing energy efficiency at the company level (WP6).
6. To carry out participatory foresight for European stakeholders of energy efficiency with a target of providing ideas for the energy efficiency vision and strategy in the European Union (WP7).
7. To compare energy efficiency policy instruments and measures and their impacts in China and the European Union (WP8).

The EUFORIE Work Packages relate to each other. The project applies different quantitative and qualitative analysis methods to energy efficiency in the EU and its Member States at different levels and from different perspectives. These analyses provide input for foresight activities, which serve European energy efficiency vision and strategy process by generating useful information. Management (WP1) and dissemination (WP9) run in parallel with the research and innovation activities.



Executive summary

Energy use, especially the use of coal, and related environmental impacts are huge in China, and the related trends are rapidly increasing because of continuous industrialisation, urbanisation, and economic growth among the fastest in the World. From the year 2000 onwards, average annual economic growth has been around 10 % in China, and the construction and industrial sectors have grown faster than the whole economy. China is nowadays the largest coal user and emitter of greenhouse gases in the World. Acid rain due to SO_2 and NO_x emissions from coal-fired energy production and poor urban air quality caused by particulate matter (PM) emissions from vehicles and local burning of coal are serious problems as well. China is also an oil exporter, so in addition to negative environmental impacts of energy use, also energy security is a reason for improving energy efficiency in China.

The purpose of this deliverable is to give an overview of the drivers and policies of energy efficiency in China, to look at how energy efficiency has affected energy use and related CO_2 emissions, and to construct scenarios about the possibility to reach the most recent Chinese policy targets introduced in the 13th FYP. The focus is on national scale, but quantitative analyses of sectoral and provincial level energy efficiency has been done in other EUFORIE deliverables.

The method used for Chinese energy efficiency drivers and policies includes literature review including a detailed analysis of recent Chinese five-year plans (FYP), China's intended nationally determined contributions (INDCs), and three most recent documents about China's policies and actions for addressing climate change, published by the National development and Reform Commission (NDRC). The impact of energy efficiency on energy use and CO_2 emissions is analysed by incremental chained two-factor decomposition analysis, which calculates the effect of change in energy efficiency related drivers (energy intensity and the primary/final energy use ratio) and other drivers to the change of energy use and CO_2 emissions. In addition, a baseline scenario and two different energy efficiency scenarios, a policy scenario and an enhanced policy scenario are constructed by using the LINDA (long-range integrated development) modeling approach. The scenarios are results of different assumptions on economic growth and fuel and electricity intensities in the different economic sectors in China, given by Chinese researchers.

The used quantitative data includes historical CO_2 emissions from fuel combustion, total primary energy supply, final energy consumption, GDP in real prices and population taken from International Energy Agency (IEA), and sectoral data and fuel and electricity data used in the ChinaLinda model is taken from the Chinese National Bureau of Statistics.

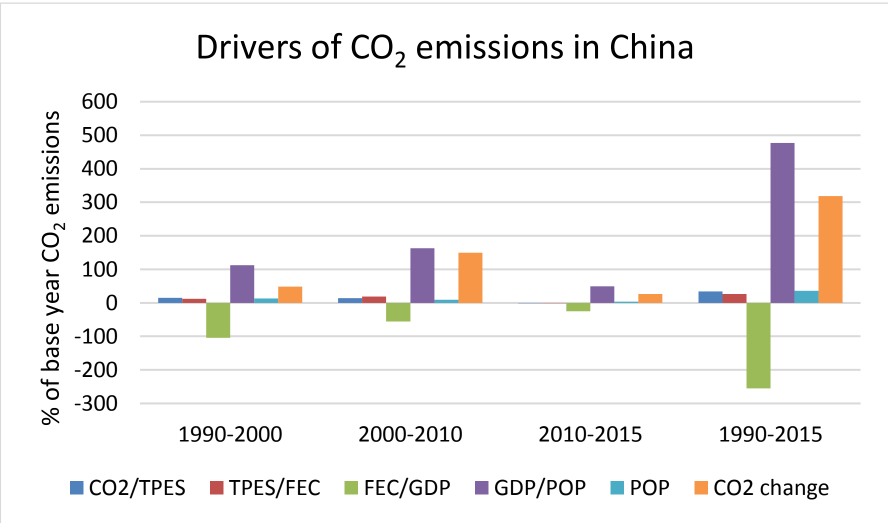
Results of the analysis show that in the five-year plans (FYP), the Chinese Government has introduced many policies and measures in order to improve energy efficiency, and the policies include many specified targets for different activities of the economy. At the national level, in the 11th FYP, quantitative targets were set for the first time for CO_2 emissions per unit of GDP, and for the share of renewable sources in the energy mix, for example. Since then, more enhanced targets have been set in the 12th FYP and the current 13th FYP for the years 2016-2020 (see the table below).

Targets related to energy efficiency for the years 2016-2020 in the 13th FYP of China.

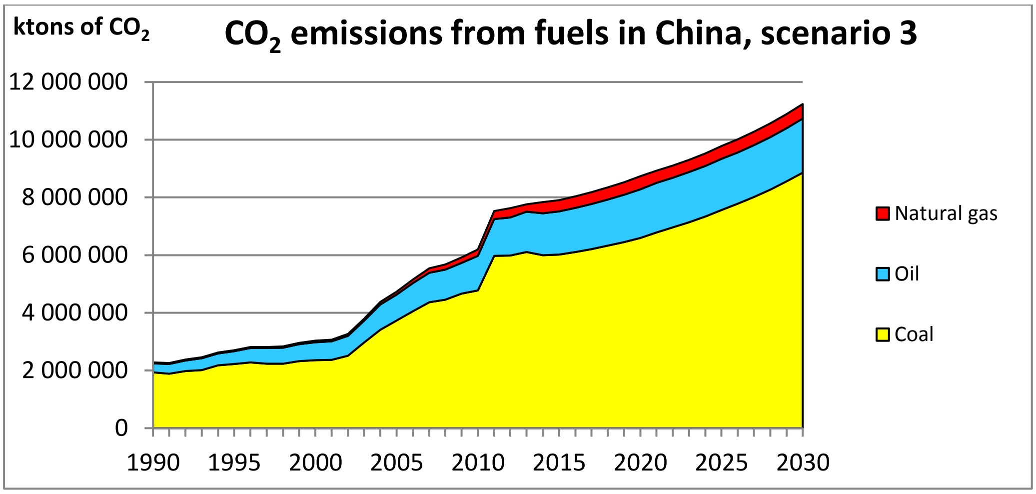
Energy consumption, reduction per unit of GDP (%)	15
Non-fossil energy (% of primary energy consumption)	3
CO_2 emissions reduction per unit of GDP (%)	18

The analysed policy documents list a very large number of detailed new policies and measures to ensure that the introduced targets will be met. Many of them are traditional command and control mechanisms, but on the other hand, a national emissions trading scheme for greenhouse gas emissions was launched in December 2017.

Effectiveness of the Chinese energy efficiency policies can be assumed from the decomposition results, because there is a rapid decrease in energy intensity of the Chinese economy, although the industrial sector has grown at a fast rate (see the figure below). Fast economic growth and the coal-dominated energy mix have increased CO_2 emissions, and only the speed of increase has slowed down by the decreased energy intensity. Population growth has also slightly increased energy use and CO_2 emissions in the long term.



The major conclusion from the analysed policy documents is that China usually reaches the relative targets set in the FYPs, and sometimes exceeds them. It is beyond this deliverable to find out is it easier to set targets realistic enough, or to meet ambitious targets with an effective control system available. The historical results are reflected also in the constructed scenarios. In the enhanced policy scenario (see the figure below), the increase of CO_2 emissions continues, because economic growth is close to the 13th FYP and decreased fuel and electricity intensities only slow down the increasing use of coal in China.



The results of this deliverable are useful for all interested in Chinese energy and climate policies, and for those who want to get an overview of China's performance in terms of energy use and CO_2 emissions. The methods used in the analysis, chained two-factor decomposition analysis and the Linda modeling approach are of interest to the researchers in the field of energy and sustainability research. The EUFORIE project has also done a comparison between China and the EU, which is available for all who are interested in further information.

Contents

Tasks of this deliverable related to WP8

This deliverable 8.1 covers the following WP8 tasks:

- Task 8.1 “National level analysis”

The results of this deliverable are also used in the comparison of EU and China in deliverable 8.5.

Abbreviations

AQSIQ	Administration of Quality Supervision, Inspection and Quarantine
BP	British Petroleum
CBRC	China Banking Regulatory Commission
CDM	Clean Development Mechanism
CECIC	China Energy Conservation Investment Corporation
CIRC	China Insurance Regulatory Commission
CMA	China Meteorological Administration
CN	China
CNCA	Certification and Accreditation Administration
CO_2	Carbon dioxide (emissions)
CSRC	China Securities Regulatory Commission
ETS	Emission trading scheme
EU	European Union
FRA	France
FYP	Five-year plan
gce	grams of coal equivalent
GDP	Gross domestic product
GER	Germany
GHG	Greenhouse gases
Gt	Gigatonnes
Gtce	Gigatonnes of coal equivalent
GW	Gigawatt
GWh	Gigawatt-hour
IMF	International Monetary Fund
IND	India
INDC	Intended Nationally Determined Contributions
ITA	Italy
JAP	Japan
kgce	kilograms of coal equivalent
kWh	kilowatt-hour
LAO	Legislative Affairs Office of the State Council
MEP	Ministry of Environmental Protection
MHRUD	Ministry of Housing and Rural-Urban Development
MIIT	Ministry of Industry and Information Technology
MOC	Ministry of Commerce
MOF	Ministry of Finance
MOST	Ministry of Science and Technology
MOT	Ministry of Transport
Mt	Million tonnes
Mtce	Million tonnes of coal equivalent
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
MWh	Megawatt-hour
NEA	National Energy Administration
NDRC	National Development and Reform Commission
NGOA	National Government Office Administration

NO_x	Nitrous oxides (emissions)
PBC	People's Bank of China
PM	Particulate matter (emissions)
PV	Photovoltaic
R&D	Research and development
RMB	Renmimbi, Chinese official currency (monetary unit: yuan)
SAC	Standardization Administration of China
SFA	State Forestry Administration
SO_2	Sulphur dioxide (emissions)
t	tonne
tCO_2e	tonnes of carbon dioxide equivalent
tce	tonnes of coal equivalent
UK	United Kingdom
USD, US$	United States Dollars

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Introduction

Energy efficiency has been recognized as the most cost-effective way of enhancing national energy security, improving economic competitiveness and reducing GHG emissions in China (Zhao et al 2017). There are potentials for energy efficiency improvement in the energy intensive sectors (Price et al 2017), such as heavy industrial branches chemical, base metal, cement, and pulp and paper (e.g. Zhang et al 2016; 2017), transportation (e.g. Khanna & Fridley 2015) and buildings (e.g. Zhou et al 2018). Chinese Government has paid more and more attentions to improve energy efficiency and issued a large amount of laws, planning systems, regulations, and other policies and measures (Hu et al 2013).

This report draws characteristics of energy use, energy efficiency, and energy efficiency policies in China. The key driving forces to improve energy efficiency will be identified, and the recent policy targets and activities are described based on the five-year plans (FYP) and other official documents, including the Intended Nationally Determined Contributions (INDC) reported by China to the UNFCCC and energy efficiency policies and measures annually reported by the National Development and Reform Commission. The effectiveness of Chinese energy efficiency policies and measures at national level will be assessed by carrying out a decomposition analysis showing the contributions of energy efficiency related drivers to total primary energy supply (TPES) and carbon dioxide (CO_2) emissions from fuel combustion. Finally, three different scenarios, based on assumptions made by Chinese researchers on economic growth and energy intensities, are made by using the ChinaLinda model These scenarios include a baseline scenario 1 and two policy scenarios (policy scenario 2 and enhanced policy scenario 3).

Characteristics of Energy use and Energy Efficiency in China

In China, due to rapid economic growth, total primary energy consumption increased from 870 Mtoe in 1990 to nearly 3,000 Mtoe in 2015 (Figure1). China is the largest energy consumer and the largest coal producer and consumer in the World. As shown in Figure 1, the primary energy mix of China is dominated by coal. Although China has made efforts to promote energy diversification, the share of coal in primary energy consumption has been around 70 % for a long time. Especially during the first te years of the 2000s, the increase in coal use was very large. However, in the most ecent years (2014-2016), the share of coal has started to decrease. The share of renewables has started to increase, but the share of gas and oil is still increasing.

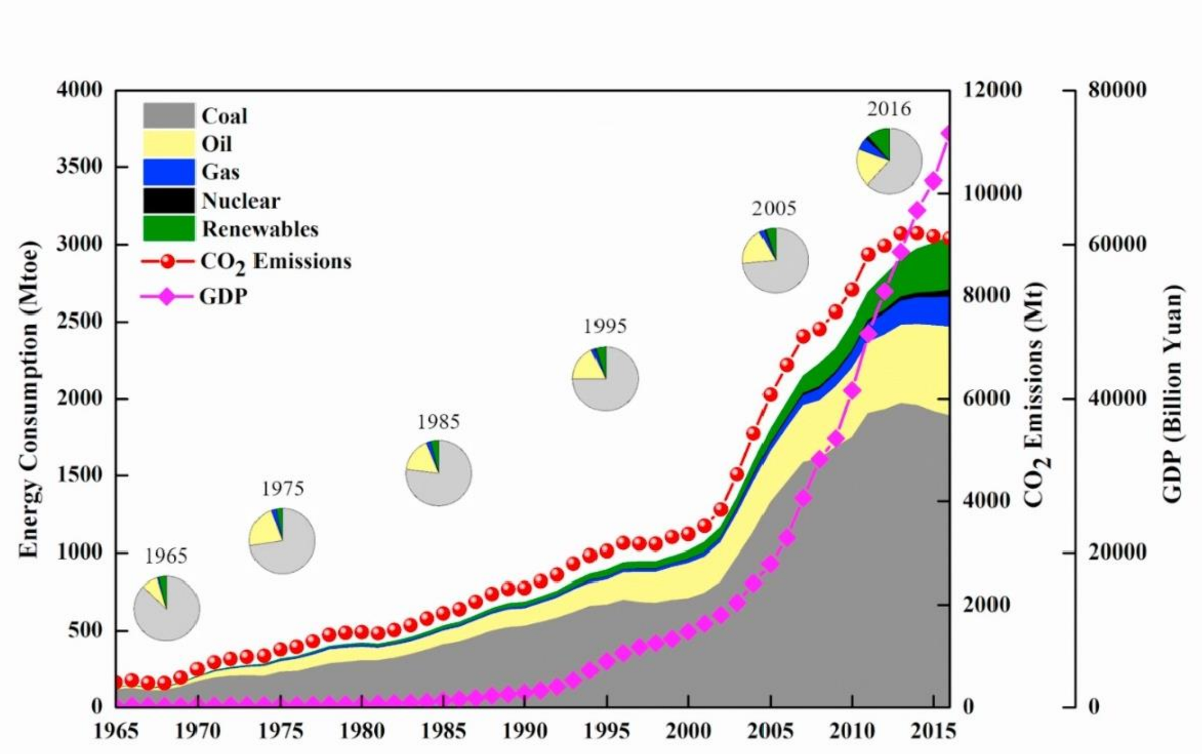

Figure1. Primary energy consumption by energy source, GDP, and CO_2 emissions in China 1965-2016. Source: Dong et al 2018.

Industry is the largest energy user in China, it accounted for 68 % of Chinese end-use energy in 2014 (Figure 2). The shares of transportation and buildings are roughly equal. The share of agriculture is only 3.4 % with a decreasing trend. The industrial sector can be divided into light and heavy industry, reflecting the relative energy intensity of the corresponding manufacturing processes. In China, the share of heavy industry is about 80 % of all industrial energy consumption. The largest energy consuming industrial braches include chemicals, ferrous metals, and building materials. The Chinese industrial sector has a great potential of energy efficiency improvements. Transportation and buildings have also been paid more attentions to in the recent years.

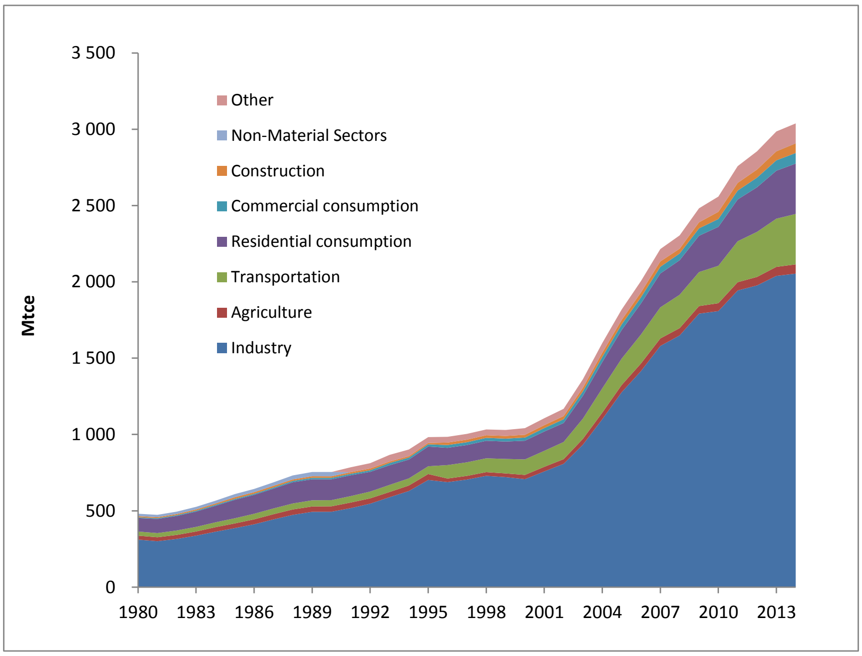

Figure 2. Pattern of end-use energy in China 1980-2014. Source: LBL 2018.

Comparing to developed countries, energy use per capita in China is relatively low but that has increased fast in the 2000s (Figure 3). In 2010, energy use per capita in China went beyond the average level of the World.

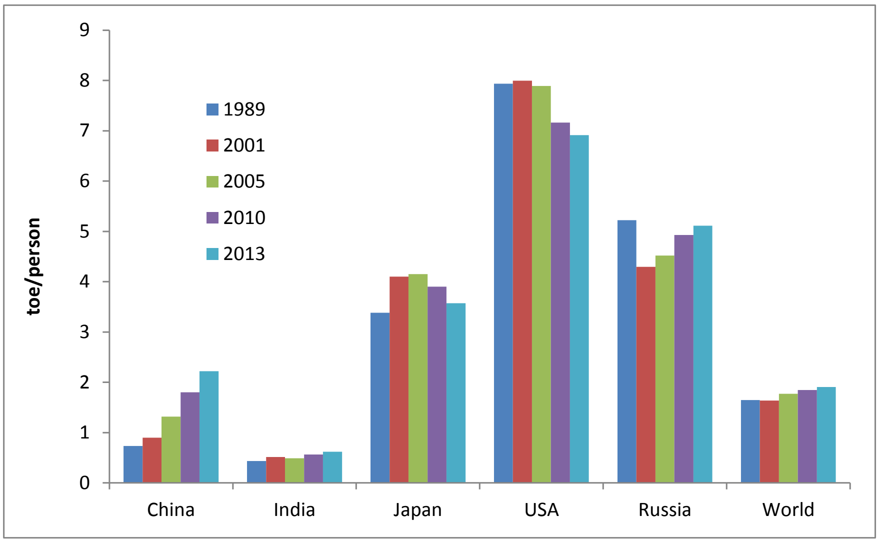

Figure 3. Energy consumption per capita in China and selected countries, 1989-2013 (for Russia, 1992-2011). Source: LBL 2018.

In terms of energy consumption per unit of GDP, China's energy intensity is much higher than in developed countries (Figure 4). The main reasons are energy-intensive economic structure and coal dominated energy mix.

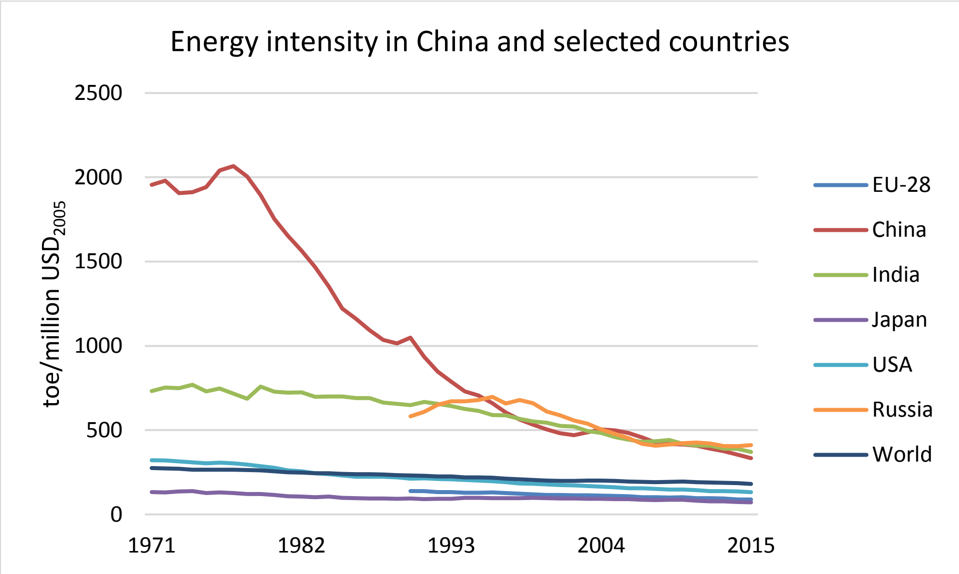

Figure 4. Energy intensity in China and selected countries 1971-2015 (toe/million USD). Data source: IEA 2017.

In terms of specific energy consumption, i.e. energy use per unit of products, the gap between China and developed countries is not so large (Table 1). China produces large amount of energy-intensive products with improved technology.

Table 1. International comparison of energy use per unit of energy-intensive products. Note: Advanced international level refers to the average level in the World leading country, for example, Italy for power generation, Japan for steel and cement, Middle East Area for ethylene. Source: Qingyi (2015).

Energy consuming process	**Specific energy consumption, China**			**Advanced international level**	
	2010	**2012**	**2014**	**2005**	**2014**
Coal-based power generation (gce/kWh)	333	325	319	288	275
Steel(large enterprises) (kgce/t)	681	674	654	610	610
electrolytic aluminium (AC) (kWh/t)	13,979	13,844	13,596	14,100	12,900
Cement (kgce/t)	134	127	124	127	118
Ethylene (kgce/t)	950	893	860	629	629

Since the early 1980s, energy efficiency improvement has been given a high priority in the Chinese energy development strategy. China has issued a lot of laws, regulations, and policies and measures, which will be reviewed in the following section. All these efforts have already led to a major progress in terms of energy intensity (Figure 4 above).

Key Driving Forces of Energy Efficiency Improvement

There are many reasons for energy conservation and improving energy efficiency in China (Su & Thomson 2016). In the following, the key driving forces of energy efficiency improvement in China will be presented, including energy security, environmental protection, and climate change.

Energy security

Energy security is an issue of imported energy sources, and the most important imported energy source in China is oil. China used to be a net oil exporter until 1993 (Yao et al 2012). Since then, China has been a net importer of oil. China has been dependent on oil imports for more than 50 percent of its total oil usage since 2008 (Figure5). By 2015, the net import of oil was almost 350 million tons, which accounted over 60 % of the country's total oil consumption (Figure 5).

If the current trends of oil production and demand continue, China's oil imports will surpass 80 % of its oil usage by 2030 (McKinsey 2009). As 80 percent of China's oil imports are shipped through the Malacca Strait (Figure 6), any serious regional conflict in that area would endanger the Chinese energy security (Zhang 2011; Yao et al 2012).

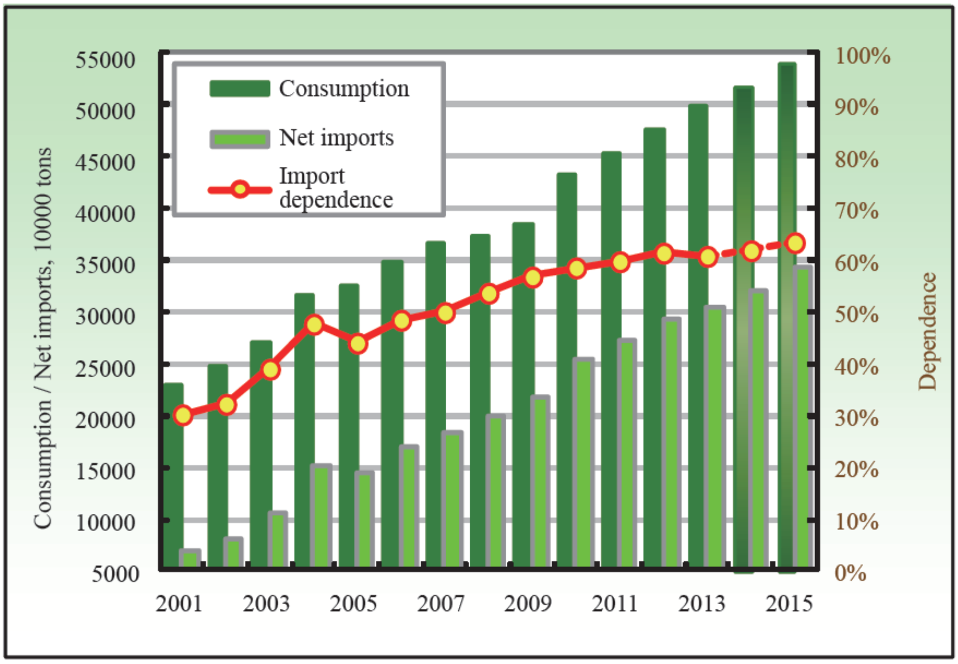

Figure 5. Net imports of oil and oil dependence on Imports in China. Source: Chunrong 2016.

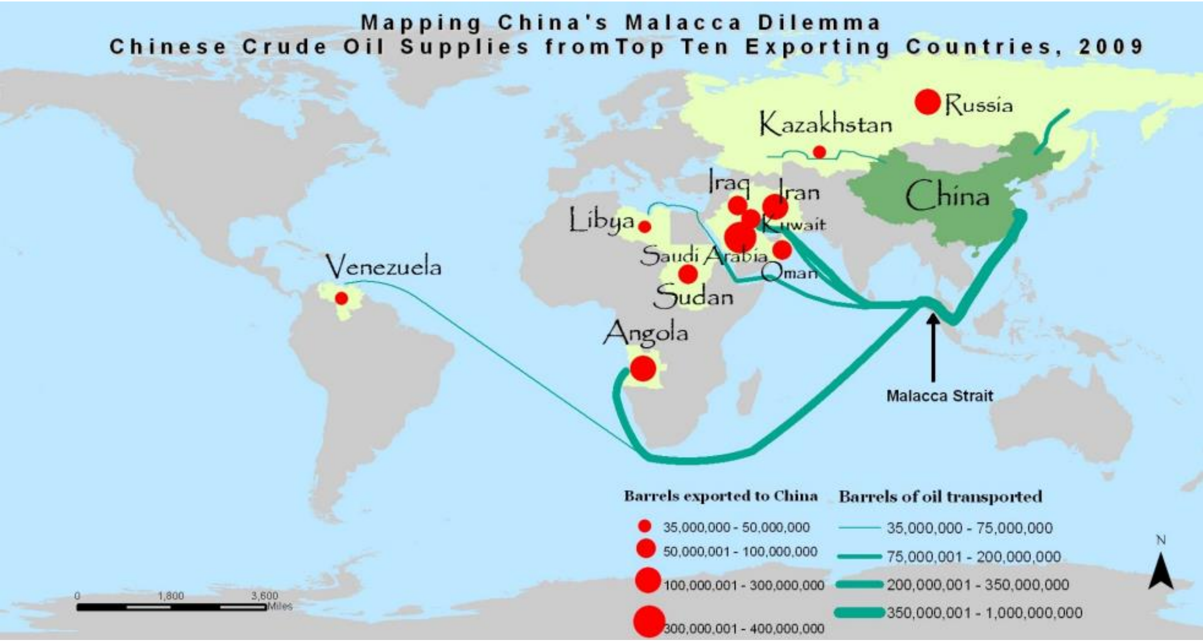

Figure 6. The Straits of Malacca and Chinese oil imports. Source: Brutlag 2011.

Environmental protection

China has abundant coal reserves, and it is the most important domestic energy source supplying more than 70 % of the total energy used over the past 30 years, and resulting in serious environmental problems (Yao et al 2012). "Acid rain", caused by emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x), is closely related to coal combustion (Gale 2016). As shown in Figure 7, SO_2 emissions reached a peak in 2006 in China, and then they have steadily been decreasing.

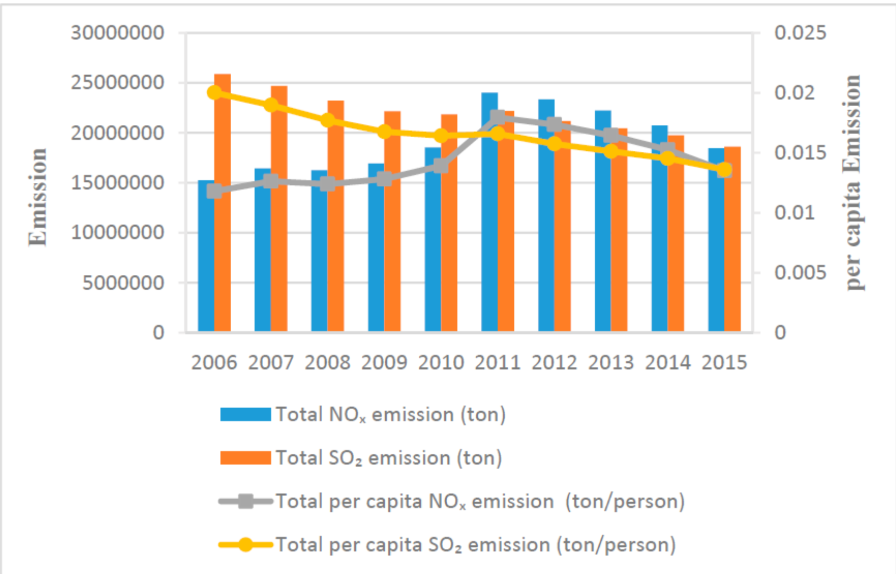

Figure 7. Total and per capita SO_2 and NO_x emissions in China, 2006-2015. Source: Azimi et al 2018.

Due to large amount of SO_2 and NO_x emissions, southern China suffers from acid rain (Figure 8).

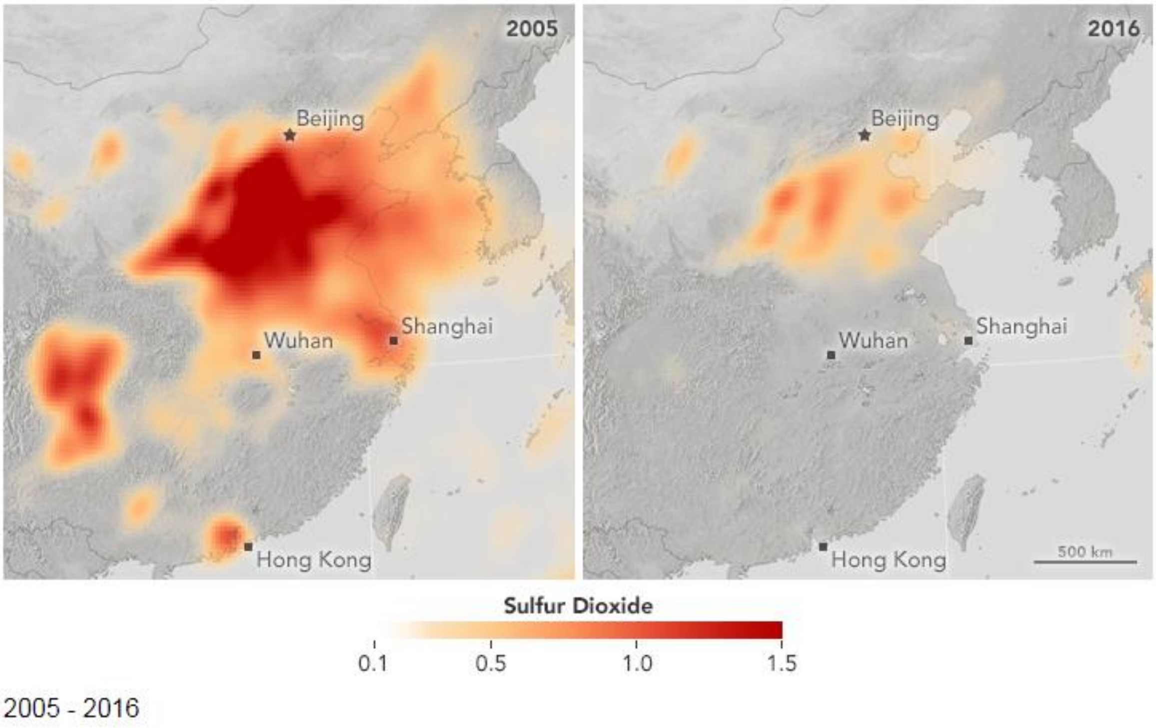

Figure 8. Acid rain areas in China in 2005 and in 2016. Source: NASA Earth Observatory 2018.

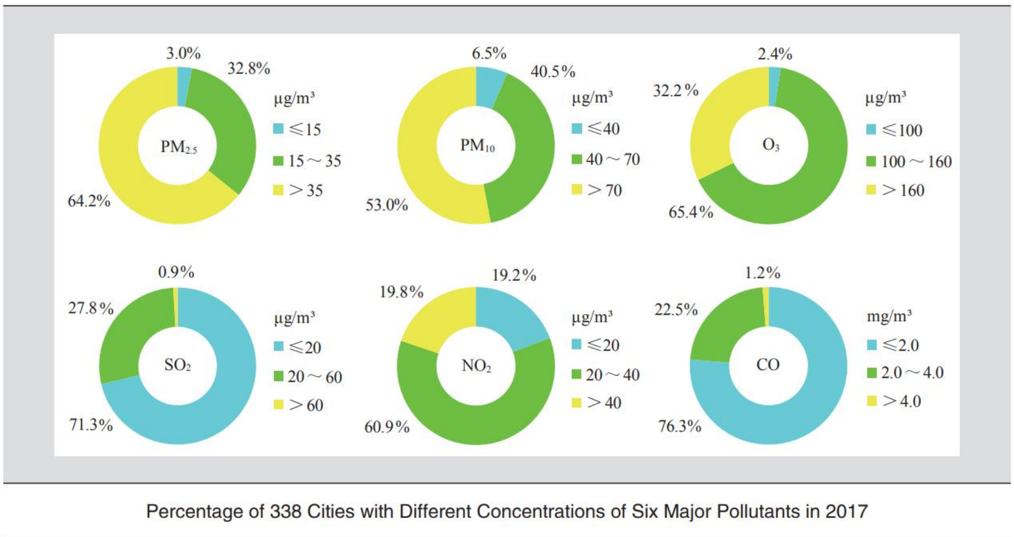

Figure 9. Concentrations of six major pollutants in Chinese cities 2017. Source: MEE 2017.

Air pollution in terms of particulate matter (PM) in large cities can lead to serious impacts on human health. According to China's Environmental Bulletin, in 2014 only in 16 out of 161 cities, annual average air quality reached the standard, and in 2015, among the 338 monitored cities nationwide, 21.4 percent reached the national air quality standards in 2015 (Jinran 2016). According to Ministry of Ecology and the Environment (MEE 2017), further improvements have been made regarding the air quality (Figure 9). Figure 10 shows annual and seasonal averages of small particles (PM2.5) concentrations in China. The urban areas, especially the municipalities of Beijing and Tianjin and the Hebei province, as well as part of the Henan Province, are the most polluted areas in China.

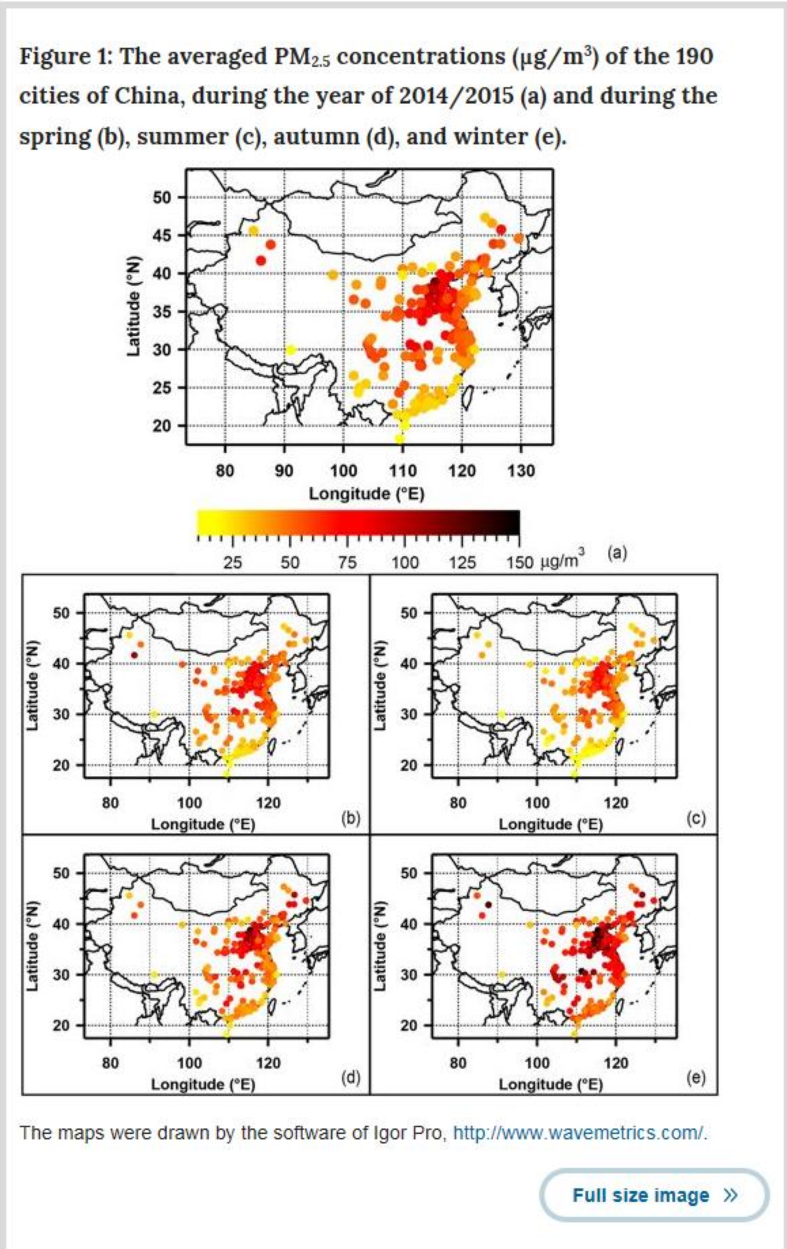

Figure 10. Annual and seasonal averages of PM2.5 concentrations in 190 cities of China. Source: Zhang & Cao 2015.

Climate Change

Fossil fuel combustion for energy production is the largest emitter of carbon dioxide (CO_2) emissions, the most important of the greenhouse gases (GHG). China's energy mix is dominated by coal, the most carbon intensive fuel. According to an estimation made by the Global Carbon Project (2018), China is the largest CO_2 emitter in terms of absolute CO_2 emissions from fuel combustion and industry (Figure 11). The trend of CO_2 emissions per capita has increased rapidly in China especially in the 2000s (Figure 12). Most of the policies and measures related to energy efficiency in China are implemented as a part of policies and actions addressed to climate change. This will be dealt with in the next chapter.

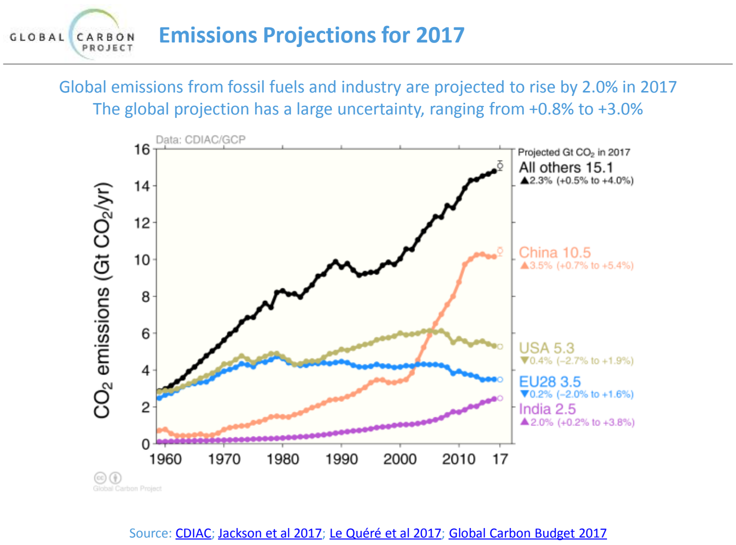

Figure 11. CO_2 emissions of Top 4 emitters in the World. Source: Global Carbon Project 2018.

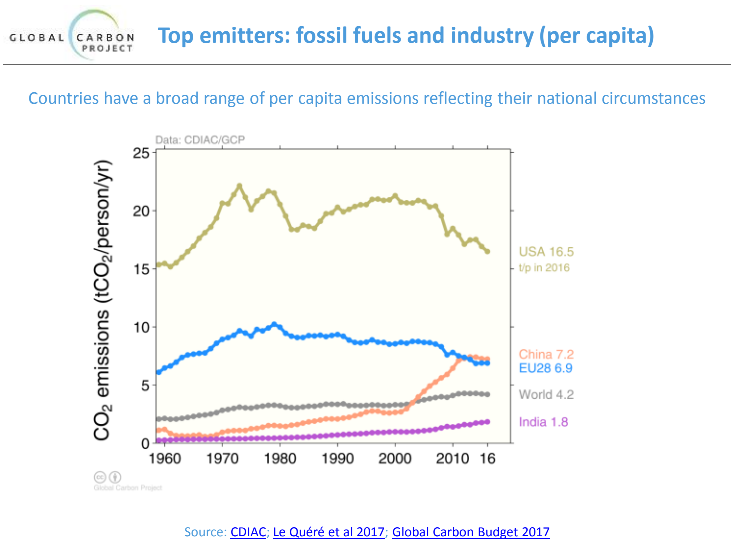

Figure 12. Different trends of CO_2 emissions per capita in the World. Source: Global Carbon Project 2018.

Policies and measures for energy efficiency improvement in China

Many policies, measures and instruments have been developed in China for promoting energy conservation and reduction of CO_2 and other harmful emissions, to cover both energy production and consumption. A wide range of policy options focus on economic structure adjustment, optimization of the energy mix, development of renewable energies, activities in the energy intensive sectors of the economy, etc. Improving energy efficiency is one of the important parts of the portfolio of policy options in China.

A brief historical review

In the 1980s, in line with China's opening and reforming process, the Chinese Government announced an equal emphasis to be put on development of energy supply and energy conservation. Many policies and measures for energy efficiency were introduced and implemented by the Government. Most of these activities were focused on the industrial sector. Offices, departments, and agencies were established at all levels of the Chinese administration to implement, manage, monitor, and enforce the numerous rules, standards, and programs related to energy conservation. The Office of Energy Conservation Work in the State Council was leading this process during that period, and the China Energy Conservation Association, the National Energy Conservation Information Network, and the Energy Conservation Technology Service Centres along with provincial Energy Conservation Agencies were also established. (Price et al 2011.)

Low interest loans for energy conservation projects, tax reliefs for energy-efficient products, and energy conservation awards for enterprises, were all used to encourage investments in energy efficiency. Energy efficiency investments were financed by China Energy Conservation Investment Corporation (CECIC), which was established for this purpose. Over 200 energy conservation centres were established during this period to provide services for energy monitoring and energy efficiency, to develop and promote energy-saving technologies, and to perform energy feasibility studies. (Price et al 2011.)

In 1997, the Chinese Government passed the Energy Conservation Law, which provides a broad guidance for the establishment of energy-efficiency policies in China. Article 20 of the Energy Conservation Law requires substantial improvement in energy efficiency of 7,200 key energy-consuming industrial facilities in China. In 1999, the Chinese Government issued "Catalogue of Outdated Technology Processes and Products", and initiated an effort to phase out non-competitive processes and products that consume too much energy, or are too polluting. (Price et al 2011.)

The 10th Five-Year Plan (FYP) was promulgated in March 2001. A number of energy efficiency policies were included in this FYP. Targets for specific energy consumption levels (energy consumption per unit of production) for key energy-intensive industries were recommended. (Price et al 2011.)

In the 11th FYP, the Chinese Government, for the first time, set a quantitative target of reducing energy intensity. The target was a reduction of 20 % during the period 2006-2010 (Kejun 2011). The national target was disaggregated into 31 provinces and other administrative regions. In order to reach the targets, several energy related programs were introduced, including ten key energy conservation projects (Table 2), and a monitoring program for 1,000 large energy users. A package of policies focusing on energy conservation was announced (Wang et al 2014). The National Development and Reform Commission (NDRC) carried out on-site assessments of the completion of the energy conservation target.

Table 2. Ten Key Energy Conservation Projects during in the 11th five year plan of China. Sources: Niederberger et al (2006); Ohshita & Price (2011); Kejun (2009; 2011); Zhijiang (2014).

No.	Key energy conservation projects	Annual energy saving potential
1	Coal-fired industrial boiler conversion and energy efficiency improvement	70 Mtce (conversion) 35 Mtce (energy efficiency)
2	Heat-power cogeneration	5 Mtce
3	Residual heat and pressure usage	2.66 Mtce(steel industry) 3 Mtce (cement industry) 1.35 Mtce (coal mining industry)
4	Oil conservation and substitution	35 Mt oil
5	Electrical machinery system energy conservation	20 billion kWh electricity
6	Energy system optimization	Strive to achieve international benchmarks of energy efficiency in steel, petrochemicals, and chemical industries
7	Construction energy conservation	50 Mtce
8	Green lighting	29 billion kWh electricity
9	Energy conservation by Government organizations	Reduce energy consumption per capita and per area of office space by 20 % within 2002-2010
10	Energy conservation monitoring and technology services system construction	Start implementation in 2006

In the 12th FYP, the Chinese Government set new absolute targets of reducing energy intensity by 16 % and carbon intensity by 17 % within the five-year period 2011-2015 (Zhang et al 2014). In order to meet these targets, the Government issued and implemented a series of policies and measures to promote energy conservation and emission reduction, including a pilot of emissions trading scheme (ETS) implemented in seven Chinese cities, and 42 low carbon pilot provinces and cities. (Zhang et al 2012.)

In June 2015, China submitted the Intended Nationally Determined Contribution (INDC) to the secretary of the United National Framework Convention on Climate Change (UNFCCC). The INDC announced the targets of achieving the peak of CO_2 emissions around 2030, and making the best efforts to peak early, by reducing CO_2 emissions per unit of GDP by 60-65 % below the level of 2005 (Sha et al 2015; see NDRC 2015a for details.)

China's Intended Nationally Determined Contributions (INDCs)

Intended Nationally Determined Contributions (INDCs) is a term used under the United Nations Framework Convention on Climate Change(UNFCCC) for reductions in greenhouse gas emissions that all countries that signed the UNFCCC were asked to publish in the lead up to the 2015 United Nations Climate Change Conference held in Paris, France in December 2015 (Chen et al 2016). China submitted Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions on June 30, 2015 (see NRDC 2015a).

Based on its national circumstances, development stage, sustainable development strategy and international responsibility, China has nationally determined its actions by 2030 as follows (Chen et al 2016):

- To achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early;
- To lower carbon dioxide emissions per unit of GDP by 60-65 % from the2005 level;
- To increase the share of non-fossil fuels in primary energy consumption to around 20 %; and
- To increase the forest stock volume by around 4.5 billion cubic meters on the2005 level.

Furthermore, China put forth many policies and measures to implement enhanced actions on climate change in the following 15 aspects (NDRC 2015a):

- Implementing proactive national strategies on climate change
- Improving regional strategies on climate change
- Building low-carbon energy system
- Building energy efficient and low-carbon industrial system
- Controlling emissions from building and transportation sectors
- Increasing carbon sinks
- Promoting the low-carbon way of life
- Enhancing overall climate resilience
- Innovating low-carbon development growth pattern
- Enhancing support in terms of science and technology
- Increasing financial and policy support
- Promoting carbon emission trading market
- Improving statistical and accounting system for GHG emissions
- Broad participation of stakeholders
- Promoting international cooperation on climate change.

There are a lot of policies and measures followed to ensure that the INDC will be achieved. Many of them focus on energy efficiency improvement in the energy production and consumption in the most potential sectors such , industry, transportation, and buildings. For example, under target of building low-carbon energy system, it emphasized (NDRC 2015a):

- To increase the share of concentrated and highly-efficient electricity generation from coal; and
- To lower coal consumption of electricity generation of newly built coal-fired power plants to around 300 grams coal equivalent per kilowatt-hour

Under the target of Building Energy Efficient and Low-Carbon Industrial System, it emphasized (NDRC 2015a):

- To embark on a new path of industrialization, developing a circular economy, optimizing the industrial structure;
- To promote the share of value added from strategic emerging industries reaching 15 % of the total GDP by 2020;
- To research and formulate greenhouse gas emission standards for key industries;
- To effectively control emissions from key sectors including power, iron and steel, non-ferrous metal, building materials and chemical industries through energy conservation and efficiency improvement; and
- To construct a recycling-based industrial system, promoting recycling restructure in industrial parks, increasing the recycling and utilization of renewable resources and improving the production rate of resource

Under the target of Controlling Emissions from Building and Transportation Sectors, it emphasized (NDRC 2015a):

- To embark on a new pattern of urbanization, optimizing the urban system and space layout, integrating the low-carbon development concept in the entire process of urban planning, construction and management and promoting the urban form that integrates industries into cities;
- To enhance low-carbonized urbanization, improving energy efficiency of building and the quality of building construction, extending buildings' life spans, intensifying energy conservation transformation for existing buildings, building energy-saving and low-carbon infrastructures, promoting the reutilization of building wastes and intensifying the recovery and utilization of methane from landfills;
- To accelerate the construction of low-carbon communities in both urban and rural areas, promoting the construction of green buildings and the application of renewable energy in buildings, improving low-carbon supporting facilities for equipping communities and exploring modes of low-carbon community operation and management;
- To promote the share of green buildings in newly built buildings of cities and towns reaching 50 % by 2020;
- To develop a green and low-carbon transportation system, optimizing means of transportation, properly allocating public transport resources in cities, giving priority to the development of public transportation and encouraging the development and use of low-carbon and environment-friendly means of transport, such as new energy vehicle and vessel;
- To improve the quality of gasoline and to promote new types of alternative fuels;

- To promote the share of public transport in motorized travel in big-and-medium-sized cities reaching 30 % by 2020; and
- To promote the development of dedicated transport system for pedestrians and bicycles in cities and to advocate green travel.

The 13th five-year plan[1]

In 2016, China introduced the current 13th FYP, which defines, among many other things, guidelines for the Chinese energy efficiency targets and policies up to the year 2020. The energy efficiency related concrete targets of the 13th FYP are collected in Table 3.

Energy issues are described in Part VII of the 13th FYP, "Modern infrastructure networks" and especially in Chapter 30 "Build a Modern Energy System", which includes sections dealing with the energy mix, energy storage and transportation networks, and smart energy systems. The focus is heavily in investments in specified energy production technologies supported by an extensive list of energy development projects (Central Compilation & Translation Press 2016):

- high-efficiency smart power systems,
- clean and efficient coal utilization (includes keeping average coal consumption per kilowatt-hour of electricity under 310 grams in existing plants and under 300 grams in new plants, but includes also increasing the proportion of coal used for power production),
- renewable energy (including construction of 60 GW new regular hydropower),
- nuclear power (installed capacity will reach 58 GW with over 30 GW under construction),
- unconventional oil and gas,
- energy transmission routes,
- energy storage facilities, and
- key energy technologies and equipment.

[1] Text in this chapter is taken from Vehmas (2018) and slightly edited. The source is an unofficial English translation of the 13th five-year plan provided by Central Compilation & Translation Press (2016).

Table 3. Energy efficiency related indicators and targets of the 13th FYP in China. Source: Central Compilation & Translation Press 2016.

Indicator	2015	2020	5-year average	Type of indicator
1. GDP (trillions of yuan)	67.7	>92.7	>6.5 %	Anticipatory
2. Labour productivity (10,000 yuan per employed person)	8.7	>12	>6.6 %	Anticipatory
19. Energy consumption, reduction per unit of GDP (%)	n/a	n/a	[15]	Obligatory
20. Non-fossil energy (% of primary energy consumption)	12	15	[3]	Obligatory
21. CO_2 emissions reduction per unit of GDP (%)	n/a	n/a	[18]	Obligatory

Notes: GDP and overall labour productivity are computed using comparable prices, while absolute figures are computed using 2015 constant prices. Figures in square brackets are five-year cumulative totals.

Energy efficiency in the consumption side is referred to in other parts of the 13th FYP (see Central Compilation & Translation Press 2016). In the context of resource use and energy conservation efforts, a plan will be implemented for catching up with and exceeding international energy efficiency standards with a focus on six major energy-intensive industries – electric power, iron and steel, building materials, chemical, petroleum and petrochemical, as well as non-ferrous metal industries. In addition, demonstration of comprehensive energy efficiency improvement efforts by 500 major energy consumers will be supported. The 13th FYP also promotes establishment of the national carbon emissions trading scheme (ETS) after the pilot phase implemented during the 12th FYP. The national Chinese emissions trading scheme was launched in December 2017. At the same time, emissions in the major carbon-emitting sectors such as power, steel, building materials and chemical industries, are strictly controlled. (Central Compilation & Translation Press 2016.)

Energy efficiency policies and measures have been integrated into national targets of energy conservation and emission reduction in China, and put a high priority at national level (Alaganthiran 2017). Targets set in the FYPs are absolute but focus mostly on relative measures such as energy intensity of production or share of a total amount.

NDRC publishes annual reports titled "China's Policies and Actions for Addressing Climate Change" (e.g. NDRC 2015b; 2016; 2017). These reports broadly deal with climate change mitigation and adaptation, but activities related to energy efficiency and energy savings are included especially under a subtitle "Conserving Energy and Improving Energy Efficiency", which can be found in all the recent reports. Focus is always the same; a large amount of policy-related documents (including legislation), typically "issued" or "promulgated" by NDRC, ministries, and other governmental bodies. Gained achievements relating to the existing relative energy intensity and CO_2 targets set in the FYP are also emphasized in absolute terms. In the following, the major energy efficiency related activities and achievements listed in the three most recent NDRC reports (NDRC 2015b; 2016; 2017) are presented.

China's Policies and Actions on Climate Change 2015

Activities on "Strengthening the management and appraisal of energy conservation" (NDRC 2015b) include the following:

- The State Council issued "2014-2015 Action Plan on Energy Conservation, Emission Reduction and Low-Carbon Development".
- NDRC issued "Notice on Further Increasing Energy Conservation Efforts to Ensure the Completion of Energy-Saving Targets of the 12th FYP Period".
- on-site assessments of the completion of energy conservation and total energy consumption targets in 31 provinces (autonomous regions and municipalities) in 2013.
- In 2014, totally 320 projects were assessed and reviewed and the energy consumption of them amounted to 290 million ton coal equivalent (Mtce), saving energy consumption by 1.5 Mtce.

Activity on "Accelerating the implementation of key energy-saving projects" (NDRC 2015b):

- A total of 1.3 billion Yuan was budgeted in 2014 to support 617 energy-saving technology transformation and industrialization projects and capacity-building projects for energy monitoring institutions, equalling to an energy saving potential of 2.68 Mtce annually.

Activities on "Further improving energy efficiency standard and labelling scheme" (NDRC 2015b) include the following:

- The "One Hundred Energy Efficiency Standard Promotion Program" was carried out by NDRC, Administration of Quality Supervision and Quarantine (AQSIQ), and the Standardization Administration of China (SAC).
- 105 compulsory energy consumption standards and 70 mandatory energy efficiency standards have been published.
- AQSIQ organized special actions of law enforcement inspections on energy-efficiency labelling of products.

Activities on "Promoting energy-saving technologies and products" (NDRC 2015b):

- NDRC released "Interim Measures for the Promotion and Management of Energy-Saving, Low-Carbon Technologies" and "Catalogue of National Key Low-Carbon Energy Technologies".
- The first and second energy-saving vehicle catalogues and the sixth energy-efficient motor catalogue.
- 100 million energy-saving bulbs are promoted via financial subsidies.
- "Implementation Plan for Energy Efficiency Leader Systems", "Catalogue of Energy Efficiency Star Products" and "Catalogue of Recommended Energy-Saving Electromechanical Equipment".

Activities on "Vigorously developing the circular economy" (NDRC 2015b) include the following:

- NDRC issued a “Circular Economy Promotion Plan” and completed the review of two circular-economy pilots-
- NDRC identified new pilots: 25 industrial park circular transformation demonstrations, 4 “urban minerals” demonstration bases and 17 meal and kitchen waste recycling pilots.
- NDRC launched “Old for Recycled and Remanufactured Products” pilot, and identified 10 pilots for promotion, and offered subsidies to the consumers.
- NRDC certified the remanufactured products and released “Catalogue of Remanufactured Products”, covering 95 remanufactured products from 27 companies.
- In 2014, China recycled a total of 245 Mtons of renewable resources, equivalent to saving 200 Mtons of coal consumption.
- NDRC issued “Opinions on Promoting the Use of Recycled Urban and Industrial Waste in Production”, and “Scheme for Implementing Key Resource Recycling and Utilizing Projects”

Activities on “Promoting energy conservation in building area” (NDRC 2015b) include the following:

- “Public Building Energy Efficiency Design Standards” was amended, and all the newly-built urban buildings began to adopt the mandatory energy efficiency standards.
- In 2014, energy-saving building area increased by 1.66 billion m^2, equivalent to an energy-saving of 15 Mtce; the energy-saving building area in China totalled 10.5 billion m^2, accounting for 38% of urban area for civil use and equivalent to an energy-saving of 100 Mtce.
- China actively developed green buildings, revised “Green Building Evaluation Standards”, and promulgated “Green Store Building Evaluation Standards”.
- In Beijing, Chongqing, Jiangsu, Zhejiang and Shenzhen, 3,241 green projects obtained green building rating labels, with a total construction area of 370 million m^2.
- China further promoted the heating metering and energy conservation renovation of existing residential buildings in northern heating areas, and completed the renovation of 830 million m^2 by the end of 2014, exceeding the 12th FYP target of 700 million m^2.
- The total area of solar thermal application in urban regions of China reached 2.7 billion m^2, the area of shallow geothermal energy application reached 460 million m^2, and the installed capacity of solar PV buildings reached 2,500 MW.
- Ministry of Housing and Rural-Urban Development (MHRUD) issued Opinions on Promoting the Development and Reform of the Building Industry.

Activities on “Driving energy conservation in transportation sector” (NDRC 2015b) are presented by NDRC as follows:

- Ministry of Transport (MOT) released “Key Outlines of Energy Conservation and Emission Reduction of Transport”.
- MOT issued “Accounting Rules for Transportation Energy-Saving and Emission Reductions and Energy Conservation Investment” (2014), which designed a low-carbon transport system frame, released the evaluation index system for green traffic, promoted energy monitoring pilots, carried out energy consumption monitoring pilots, and organized energy consumption statistics and a monitoring pilot for highway and waterway transport enterprises.

- MOT adhered strictly to the implementation of fuel consumption standard for road-transport vehicles and released over 30,000 standard-reaching models.
- MOT issued “Fuel Consumption Limits for Passenger Vehicles”, “Fuel Consumption Limits for Heavy Commercial Vehicles”, and “Opinions on Speeding up the Promotion and Application of New Energy Vehicles in Transportation Industry”.
- 83,900 new energy vehicles were manufactured in 2014 and 156,200 new energy vehicles were manufactured in the first 9 months of 2015.
- Energy consumption per unit transport volume decreased by 2.4 % in 2014, while that of ships by 2.3 % and the port saw a fall of 2.5 % in comprehensive unit consumption.
- In 2014, the Civil Aviation Administration issued “Guide for Civil Aviation Energy Conservation Special Fund Project” (2013-2014) and appropriated 528 million Yuan to support the implementation of 238 energy-conservation and emission-reduction projects.
- In 2014, the energy consumption per passenger of airport fell by 8.6 %.

Activities on “Promoting energy conservation in public institutions” (NDRC 2015b) include the following:

- NGOA and AQSIQ issued “Notice on Strengthening Energy Resources Measurement Work in Public Institutions”, revised “Regulations on Energy Resources Consumption Statistics System for Public Institutions”, promulgated “Reference Catalogue of Energy-Saving and Water-Saving Technologies and Products for Public Institutions”, and released “Notice on Energy Resources Conservation Arrangements for Public Institutions”.
- Inspection of the 2nd batch of energy-saving public institutions and energy resources conservation assessment of central state organs was carried out, reporting of energy conservation information in public sectors was strengthened, and two R&D projects on energy efficiency technologies in public institutions were promoted.

In total, China’s energy consumption per unit of GDP decreased by 4.8 % in 2014, the largest decrease during the 12th FYP period. The energy consumption per unit of GDP dropped by 13.4 %, by saving energy consumption by 600 Mtce, which equals to a reduction of 1.4 billion tons of CO_2 emissions (NDRC 2015b).

China's Policies and Actions for Addressing Climate Change 2016

Activities on “Enhancing the assessment and management of energy-saving accountabilities” (NDRC 2016):

- In 2011, the State Council issued “Comprehensive Work Plan on Energy Conservation and Emission Reduction during the 12th FYP Period”, which (1) allocated energy conservation targets to local governments, (2) implemented an assessment system and (3) released quarterly reports on the completion of regional energy conservation targets.

- In 2014, the State Council released the "Action Plan on Energy Conservation, Emission Reduction and Low-carbon Development".
- During the 12^{th} FYP period, the NDRC made an assessment of the completion of energy conservation targets by provincial governments.

Activities on "Improving energy efficiency standards and labelling" (NDRC 2016):

- China further advanced the implementation of the "Project of Promoting One Hundred Energy Efficiency Standards" and issued 221 national energy conservation standards.
- The Certification and Accreditation Administration (CNCA) and the NDRC jointly released the "Certification Rules of Energy Management System".
- AQSIQ and NDRC jointly issued "Management Measures for Certification of Energy-Saving and Low-Carbon Products".
- In 2014, seven ministries including the NDRC jointly issued "Notice of Publishing the Implementation Plan for the Energy Efficiency Leaders Scheme" covering end-use products, energy-intensive industries and public institutions.
- In 2015, China worked out implementation rules for the "Energy Efficiency Leaders" scheme and launched the evaluation and selection of products and enterprises as the leaders.

Activities on "Promoting energy-saving technologies and products" (NDRC 2016):

- Ministry of Industry and Information Technology (MIIT) issued "Industrial Energy Conservation Plan for the 12^{th} FYP Period".
- MIIT released "Implementation Plan for the Special Action of Industrial Energy Conservation and Green Development" and the State Council issued "Opinions on Enhancing Energy Conservation and Emission Reduction in Internal Combustion Engine Industry".
- NDRC released "Interim Management Measures for the Promotion of Energy-Saving and Low-Carbon Technologies", and two editions of "Catalogue for the Promotion of National Key Energy-Saving Technologies".
- MIIT released "Catalogue for National Key Advanced Energy-Saving Technologies for Motors" and "Guidance Catalogue of Energy-Saving Technologies for Communications Industry".
- MIIT has compiled six editions of "Catalogue of Recommended Energy-Saving Mechanical and Electrical Equipment", and issued "Catalogue of Energy Efficiency Star Products".
- MIIT has carried out a project of bringing the benefits of energy-efficient products to the people, and promoted the use of energy-efficient products such as air conditioners, vehicles, electrical machines and lighting products.

Activities on "Boosting energy conservation in building area" (NDRC 2016):

- Ministry of Housing and Urban-Rural Development (MOHURD) issued "Special Energy Conservation Plan for Buildings during the 12^{th} FYP Period" and "Notice of Further Promoting Energy Conservation in Public Buildings".
- During the 12^{th} FYP period, heating measurement and energy efficiency renovations had been completed for one billion m^2 of existing residential buildings, and energy efficiency

renovations have been carried out for 70.9 million m^2 of existing residential buildings in specific regions.

- By the end of 2015, all new urban residential and public buildings began to follow energy-saving design standards, and more than 10,000 public buildings had received energy audits, and dynamic monitoring of energy consumption was carried out in over 8,000 buildings.
- “Development Plan on Green Buildings and Green Ecological Cities and Districts during the 12th FYP Period”, “Management Methods of Green Building Materials Evaluation Labels”, “Action Plan on Promoting the Production and Application of Green Building Materials”. “Green Building Evaluation Standards”, and “Notice on Further Boosting Renewable Energy Application in Buildings” have been released.
- By the end of 2015, 3,979 projects had obtained green building labels, with a total construction area exceeding 450 million m^2.

Activities on “Promoting energy conservation in transportation area” (NDRC 2016):

- MOT issued “Guidelines on the Development of Green, Circular, Low-Carbon Transport”, “Guidelines on Building Low-Carbon Transport System”, and implemented “Guidelines on Speeding up Energy Conservation and Emission Reduction in the Civil Aviation Industry”.
- MOT piloted natural gas-fuelled vehicles and vessels, implemented fuel consumption standards. identified vehicle models meeting the standards, and recommended trailer models
- Ministry of Finance (MOF) issued “Notice on Preferential Vehicle and Vessel Tax Policies for Energy-Saving and New Energy Vehicles and Vessels”.
- Ministry of Science and Technology (MOST) implemented a demonstration project promoting the use of 1,000 energy-saving and new-energy vehicles.
- The civil aviation industry kept increasing investment in energy conservation and emission reduction, with more than 1,200 projects.
- In 2015, CO_2 emissions per unit of transport turnover in commercial vehicles and vessels decreased by 15.9 % and 20 % compared to the 2005 level, respectively , and fuel consumption per ton-kilometer and CO_2 emissions per ton-kilometer in the civil aviation sector decreased both 13.5 %.

Activities on “Promoting energy conservation in public institutions” (NDRC 2016):

- The State Council issued “Plan for Energy Conservation in Public Institutions during the 12th FYP Period” and “Opinions on the Implementation of Promoting Energy and Resource Conservation and Boosting Ecological Progress in Public Institutions”, and the energy saving management system in public institutions was preliminarily established.
- The Ministry of Commerce (MOC) developed industry standards for the Green Shopping Malls and carried out demonstration in this regard.
- The average annual growth rate of energy consumption in public institutions decreased by 1.43 percentage points in the 12th FYP period compared to the previous five years, meeting the energy conservation target.

Activities on “Speeding up the development of circular economy” (NDRC 2016):

- The State Council released “Strategy and Short-Term Action Plan for the Development of Circular Economy”, and NDRC issued annual “Circular Economy Promotion Plans”.
- NDRC together with other ministries identified 49 demonstration bases for Urban Minerals, 100 pilots for the demonstration of upgrading industrial parks to make their operations more circular, 100 pilot cities of recovering resources from kitchen waste, 101 circular-economy demonstration cities and counties, and 28 circular-economy education demonstrations.
- The NDRC, the MIIT and other ministries carried out the second batch remanufacturing pilots with 28 enterprises identified and a pilot of “Replacing Old by Remanufactured Product” with 10 enterprises involved.
- MIIT released five editions of “Catalogue of Remanufactured Products”.

In total, China’s energy consumption per unit of GDP reduced by 5.6 % in 2015, which was the best achievement in the 12th FYP period. Energy consumption per unit of GDP during the 12th FYP period accumulatively dropped by 18.4 %. In 2015, China’s energy consumption reached 4.3 Gtce, with an increase of 0.9 %. The average annual growth rate of national energy consumption was 3.6 % in the 12th FYP period, 3.1 percentage points lower than in the 11th FYP period. (NDRC 2016.)

China's Policies and Actions for Addressing Climate Change 2017

In 2017, NDRC published “China’s Policies and Actions for Addressing Climate Change 2017” (NDRC 2017). This report deals with activities directly related to energy efficiency under the title “Conserving Energy and Improving Energy Efficiency” as follows:

Activities on “Strengthening target binding and policy driving” (NDRC 2017)

- The State Council released the “Comprehensive Work Plan for Energy Conservation and Emissions Reduction during the 13th FYP Period”, which made an overall arrangement for energy conservation in the five years and decomposed the targets of energy consumption cap and intensity control (double control) to provinces (autonomous regions and municipalities)
- National Energy Administration (NEA) issued the “Guiding Opinions on Energy Work” in 2016, putting forward the target of controlling total energy consumption.
- In 2016, NDRC entrusted by the State Council conducted evaluation and appraisal of provincial government responsibility for energy conservation targets, and clarified the energy consumption cap and intensity targets in 2016 and 2017.
- NDRC carried out on-site evaluation of "double control" 2016 target completion of provincial governments.
- NDRC, MIIT, MOST, MOF and other ministries jointly issued “13th Five-Year Action Plan for Energy Conservation”, which set forth actions such as the promotion of energy-efficient products.

Activities on “Enhancing energy efficiency management and institutional construction” (NDRC 2017):

- In 2016, NDRC convened the coordinator meeting of the "State Council Leading Group for Energy Conservation and Emissions Reduction" to coordinate the work for energy conservation during the 13th FYP period.
- NDRC issued the "Measures for Energy Conservation Supervision" and the updated "Measures for Energy Efficiency Examination of Fixed-Asset Investment Projects".
- NDRC and SAC jointly developed the "Plan for Building an Energy Efficiency Standard System"
- In May 2016, NDRC and AQSIQ jointly released the revised "Administrative Measures for Energy Efficiency Labelling".
- By the end of 2016 there are totally 35 products for which energy efficiency labels are unveiled officially.

Activities on "Pushing forward energy conservation in key areas" (NDRC 2017):

- In 2016, the Energy Efficiency Leader program continued to implement and NDRC and AQSIQ released the "Catalog of Energy Efficiency Leaders" for refrigerators, flat-panel televisions, and speed-adjustable room air conditioners.
- NDRC invested in key energy conservation projects, including energy efficiency improvement of key energy users, energy conservation renovation of key industries, promotion of energy management contracting, urban road lighting, and renovation of airports, stations and ports.
- The "Administrative Measures for Energy Efficiency of Key Energy Users" was issued, which urged the national key energy users to implement the "Hundred/thousand/ten thousand" energy conservation actions and advance the construction of on-line energy efficiency monitoring system.
- The pilots of compensated use of energy and trading of energy use were also underway.
- The Ministry of Housing and Urban-Rural Development (MOHURD) proceeded with the Green Building program.
- MOT stepped up efforts to build a modern integrated transportation system, and established and improved the green transportation regulation and standard system.
- National Government Office Administration (NGOA) and NDRC jointly issued the "13th FYP for Energy and Resource Conservation of Public Institution", and carried out energy efficiency assessment of public institutions.
- 22 provinces (autonomous regions and municipalities), including Shanghai and Henan, unveiled the regional five-year plans for energy and resource conservation of public institution.

In 2016, China's energy consumption was 4.36 billion tons of coal equivalent (tce). The annual growth of energy consumption was 1.4 %, i.e. 2.2 and 5.3 percentage points lower than the average annual growth during the 12th and 11th FYP periods, respectively. The energy consumption per unit of GDP fell by 5 % year on year, exceeding the target set for 2016, equivalent to energy saving of 230 million tce and CO_2 emission reduction of 500 million tons. (NDRC 2017.)

In other words, energy consumption is still increasing in China, but the increase has slightly slowed down. Because the Chinese economy has a continuous trend of fast growth, improvement in energy intensity seems to be great. However, China (and other fast developing countries) clearly show the power and importance of the Jevons paradox (Polimeni et al 2009).

In the NRDC (2017) annual report on Chinese activities in addressing climate change, activities under the title "Planning Formulation and System Construction" deal also with energy efficiency. According to the report, since 2016, the Chinese Government has accomplished positive achievements through efforts on strengthening planning, improving schemes and mechanisms, enhancing laws, regulations and standards, promoting carbon emission trading system, and boosting green low-carbon finance (NDRC 2017).

Activities under "Strengthening Planning" (NDRC 2017):

- In October 2016, the State Council issued the "Work Plan for Controlling Greenhouse Gas Emissions during the 13th FYP Period". The work plan explicitly stated that provinces (including autonomous regions and municipalities) shall incorporate the reduction of CO_2 intensity into the local economic and social development plans, and other documents. As of June 2017, totally 18 regions had released such work plans.
- MIIT promulgated the "Green Development Plan for Industry" (2016-2020) to accelerate ecological civilization construction and promote green development of the industrial sector.
- NDRC and NEA unveiled the "Energy Production and Consumption Revolution Strategy" (2016-2030) and the "13th FYP for Energy Development", providing overall planning for energy development in the five years.
- NDRC released the "13th FYP for Renewable Energy Development".
- NEA released the "13th FYP for Energy Technology Innovation", as well as the 13th FYPs for solar power, wind power, oil, natural gas, and coal industries.
- MOHURD unveiled the "13th FYP for Building Energy Efficiency and Green Buildings".
- MOST, Ministry of Environmental Protection (MEP) and China Meteorological Administration (CMA) jointly developed and published the "Special Plan for Scientific and Technological Innovation to Address Climate Change during the 13th FYP Period".
- State Forestry Administration (SFA) issued the "Highlights of the Action to Address Climate Change in Forestry during the 13th FYP Period" and the "13th FYP for Forestry", and formulated the "Provincial Work Plan for Addressing Climate Change in Forestry during 2017-2018".

Activities under "Improving Schemes and Mechanisms" (NDRC 2017):

- In 2016, the 3rd term of National Climate Change Expert Committee was set up, comprising of members in the fields of atmosphere, oceans, hydrology, geology, ecology, forestry, energy, transportation, building, economics, law and international relations. It continued the work related to the low-carbon development strategy toward 2050, carbon market mechanism and construction, green low-carbon development pattern, climate change science and policy study, etc.
- Professional research agencies on climate change and low-carbon development were continuously improved at provincial and city levels, contributing to the formulation of climate change research system.

- Provincial leading groups for climate change were formed in 30 regions.
- Climate change departments or offices were established or branched to other departments under the Development and Reform Commission of 29 provinces, autonomous regions and municipalities.
- Many supporting agencies were founded independently or within universities, research institutions and public institutions in 14 regions such as Beijing, Zhejiang, and Guangdong.

Activities under “Strengthening target-oriented responsibility assessment” (NDRC 2017):

- The “Work Plan for Controlling Greenhouse Gas Emissions during the 13th FYP Period” required strengthening the evaluation and assessment of provincial governments on GHG emissions control and establishing an accountability system.
- NDRC formulated and issued the “Measures for Assessment of Provincial Government Fulfillment to Control Greenhouse Gas Emissions during the 13th FYP Period”, and organized the 2016 assessment of 31 provinces (autonomous regions and municipalities).
- In line with the assigned targets of carbon intensity controlling by national government, all provincial governments formulated the assessment measures and work plans, including setting reasonable annual targets and completing annual self-assessment.
- In July 2016, the NDRC organized working groups to carry out on-site assessment of provinces (autonomous regions and municipalities), and the assessment results were used as an important indicator for the evaluation of provincial government and department leaders, the reward and punishment of officials, as well as the tenure and appointment examination of leaders.
- 29 pilot low-carbon provinces or cities broke down the objectives and tasks of controlling GHG emissions to sub-regional districts and counties, wherein 22 conducted the assessment.

Activities under “Enhancing Laws, Regulations and Standards” (NDRC 2017):

- The Climate Change Law and the Regulations on Carbon Emissions Trading Administration were included in the "Research Projects" and "Preparatory Projects" of the “Annual Legislative Program of the State Council” 2016.
- In line with the legislation plan and task allocation, the special study on climate change legislation was deepened, the laws drafted, and the views of all stakeholders solicited on the draft of the “Regulations on Carbon Emissions Trading Administration”.
- China strengthened international cooperation and exchanges and expands international influence in the field of climate change legislation through bilateral cooperation mechanisms with Germany, France and the UK, and multilateral cooperation platforms with the United Nations and other organizations.
- Shijiazhuang City and Nanchang City respectively issued the “Regulations on Promotion of Low-Carbon Development” to accelerate the related local legislation process.

Activities under “Improving standard and labelling system” (NDRC 2017):

- By the end of 2016, NDRC has registered 200 project-based carbon emission reduction accounting methodologies in 12 batches, covering several key sectors such as industry, power, energy, building and agriculture sectors.
- The Certification and Accreditation Administration (CNCA) released the "General Norms for Organization of Greenhouse Gas Emissions Verification".
- In 2016, NDRC, AQSIQ and CNCA jointly issued the second-batch of "Catalog of Low-carbon Product Certification", adding three new products including building ceramic tiles (plates), tires, and textile fabrics.
- The General Office of the State Council issued the "Opinions on Establishing a Uniform Standard, Certification and Labelling System for Green Products", suggesting combining low-carbon, eco-friendly, and organic product certificate into one unified certification of green products.
- AQSIQ actively strived for and took leading role of many climate-change-relate technical institutions under the ISO.

Activities under "Enhancing Carbon Emission Trading System" (NDRC 2017):

- In January 2016, NDRC issued the "Circular on Making Improvements to Key Work Related to the Launch of the National Carbon Emissions Trading Market" to implement key work related to the national carbon market, which included accounting, reporting and verification of historical carbon emissions of covered enterprises, cultivation and selection of third-party verification units, and capacity building of stakeholders.
- In 2017, the Legislative Affairs Office (LAO) of the State Council, in conjunction with NDRC, continued the legislative review of the "Interim Regulations on Administration of Carbon Emissions Trading".
- NDRC drafted the "Administrative Measures for Carbon Emissions Reporting of Enterprises and the Administrative Measures for Third-Party Verification Units of Carbon Emissions", designed and improved the allowance allocation methodology, and completed tentative calculation of allowances for enterprises in power generation, electrolytic aluminium and cement sectors.
- NDRC evaluated and selected agencies to undertake the construction, operation and maintenance of the national registry and trading system for carbon emissions, and studied the promotion of reformation of Clean Development Mechanism (CDM) and voluntary GHG emissions reduction trading mechanism.
- Since launched by NDRC in 2011, the carbon emissions trading pilots have made progress in Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei and Shenzhen, through which a full-fledged and large-scale carbon emission trading pilot market with distinct characteristics has taken the initial shape.
- As of September 2016, the seven pilot carbon markets covered nearly 3,000 key enterprises from more than 20 industries and traded 197 million tons of carbon dioxide equivalent (tCO_2e), involving a total turnover of about 4.516 billion yuan.
- Currently, 3-4 rounds of compliances with emission trading allowance have been completed, showing its effect on emission reduction primarily.

- In addition, Fujian released the "Interim Measures on Administration of Carbon Emissions Trading in Fujian Province" in September 2016 with a coverage of 227 enterprises from 9 industries such as electric power, petrochemicals, aviation and ceramics.
- Fujian officially initiated its carbon market in December 2016, with the trading volume of 786.3 thousand tCO_2e and turnover of 18.2265 million yuan on the first day.

Administrative Measures for Voluntary GHG Emissions Reduction Trading and conducted the revision of guidelines for assessment, approval and verification of voluntary GHG emissions reduction trading projects (NDRC 2017):

- By March 2017, China has developed 198 methodologies for voluntary GHG emissions reduction, accredited 12 institutions to assess and approve voluntary GHG emissions reduction projects and verify voluntary GHG emissions reduction, as well as accumulatively disclosed 2,871 approved voluntary GHG emissions reduction projects and 1,315 registered projects.
- As of December 2016, the national registry for voluntary GHG emissions reduction trading was connected with the carbon emissions trading platforms of seven pilot areas, Fujian and Sichuan, with the cumulative trading volume of voluntary GHG emissions reduction reaching 81.11 million tCO_2e and cumulative turnover about 720 million yuan.

Activities under "Boosting Green Low-Carbon Finance" (NDRC 2017):

- The "Work Plan for Controlling Greenhouse Gas Emissions during the 13th FYP Period" put forward efforts on climate change and low-carbon development, by (1) introducing comprehensive policies, (2) improving climate investment and financing mechanisms, (3) giving into play the role of the China CDM Fund, and (4) actively using the public-private partnership (PPP) mode and green bonds. Furthermore, it proposed to carry out the climate investment and financing pilot focusing on investment policy guidance and financial support enhancement during the 13th FYP period.
- People's Bank of China, MOF, NDRC, MEP and Regulatory Commissions of Banking (CBRC), Securities (CSRC) and Insurance (CIRC) jointly issued the "Guiding Opinions on Building a Green Financial System", starting the construction of Chinese green financial system and policy framework.
- The G20 Green Finance Study Group was set up, which put green finance in the G20 Summit Agenda and completed the G20 Green Finance Synthesis Report for the first time.
- The exploration of green finance was active at the local level. The Shanghai Stock Exchange and the Shenzhen Stock Exchange issued the respective notice to carry out the pilot of green corporate bonds and advance the pilot of green bonds; Inner Mongolia explored the establishment of local environmental fund; and Shanghai Pudong Development Bank successfully issued China's first green financial bonds.
- In 2017, the 176th State Council Executive Meeting examined and adopted the Integrated Plan to create pilot zones for green finance reformation and innovation in five provinces (autonomous regions), namely Zhejiang, Jiangxi, Guangdong, Guizhou and Xinjiang.

- CSRC published the Guiding Opinions of China Securities Regulatory Commission on Supporting the Development of Green Bonds to guide the exchange-dominated bonds market further serving the green industry.
- PBC, CBRC, CSRC, CIRC and SAC jointly released the “Plan for Building and Developing a Standard System of Financial Industry” (2016-2020), which focused on promoting the standardization of green finance.
- NDRC actively conducted studies on climate financing pilot, and cooperated with CBRC to revise the Green Credit Statistical System, which intended to include "low-carbon credit" into green statistics, establish the classification and statistical system for low-carbon credit projects, and improve the environmental benefit measurement methodologies.

Impacts of energy efficiency policies in China

In this chapter, the analysis focuses on identifying the reasons for changes in total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2) in China during the period 1990-2015. Both TPES and CO_2 will be decomposed into the effect of pre-defined drivers identified in equations (1) and (2) below. Based on the results from the decomposition analysis, something can be perhaps said about the effectiveness of the energy efficiency policies listed earlier in this report.

The drivers of total primary energy supply (TPES) in China are identified in equation (1), and drivers of CO_2 emissions from fuel combustion are identified in equation (2).

$$TPES = \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP \qquad (1)$$

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP \qquad (2)$$

In the equations (1) and (2), CO_2 is carbon dioxide emissions from fuel combustion, TPES is total primary energy supply, FEC is final energy consumption, GDP is gross domestic product in real prices using exchange rates (presented in 2005 USD), and POP is the amount of population. All data used in the decomposition analysis, is taken from International Energy Agency (IEA 2017).

Driver CO_2/TPES describes the effect of change in carbon intensity of the primary energy mix. If the effect is negative, i.e. decreases CO_2 emissions, then the low carbon energy sources (renewables such as hydro, wind, solar and biomass, as well as nuclear) have increased their share in the energy mix. This increase is an important policy target in China.

Driver TPES/FEC is the ratio between primary and final energy use. It can be used as an indicator of the efficiency of the entire energy transformation system. The closer the ratio is to value 1, the more efficient the system. If this driver has a negative effect on either TPES or CO_2 emissions, the efficiency of the energy transformation system has increased, and vice versa. Statistical treatment of electricity produced from certain renewable energies (produced electricity equals to primary energy) may disturb the usefulness of this driver, but it describes change in the energy mix to some extent. Identifying the effect of changing energy mix requires a decomposition method capable of handling structural effects.

Driver FEC/GDP describes energy intensity of the economic productive system. If this driver has a negative effect to TPES and CO_2 emissions, energy intensity has decreased. This may be, partly, a result of increasing energy efficiency, but the effect includes also the effect of structural change taken place in the economy during the studied period. The effect of structural change can be identified and analyzed, but for it a decomposition method equipped for it is required, and relevant sectoral data must also be available for this kind of analysis.

Decreasing energy intensity is an important policy target in China. Energy intensity is often dealt with primary energy (TPES/GDP) instead of final energy which is used here. The effect of primary energy intensity can be easily calculated from the results below by summing up the effects of TPES/FEC and FEC/GDP.

Drivers GDP/POP and POP describe change in economic activity and population, respectively. Positive effect of these drivers are traditional policy targets which have not been put under question, although their link to environmental impacts at the global level has been shown a long time ago, for example in the discussion about the IPAT identity which identifies population, affluence and technology as the main drivers of environmental impact (York et al 2003). The IPAT identity is also in the background of decomposition method applied in this report (Vehmas et al 2017; cf. Vehmas 2009).

Effects of the factors identified in the equations (1) and (2) are calculated by using the chained incremental Sun-Shapley decomposition methodology (Vehmas et al 2017; 2018; Vehmas 2018). The annual results regarding the energy efficiency related drivers are presented in Figures 14 and 15 for TPES and in Figures 17-19 for CO_2 decomposition, respectively. In TPES decomposition, energy efficiency related drivers include TPES/FEC (Figure 14) and FEC/GDP (Figure 15), and in the CO_2 decomposition, energy efficiency related drivers are CO_2/TPES (Figure 17), TPES/FEC (Figure 18) and FEC/GDP (Figure 19). Numerical values for all drivers, also for longer periods are available in Table 4. Results for other periods than those in Table4 can be easily calculated by summing up the annual changes for the corresponding period. Change in the decomposed variables TPES and CO_2 emissions from fuel combustion, are presented in Figures 13 and 16, respectively, as well as in Table 4.

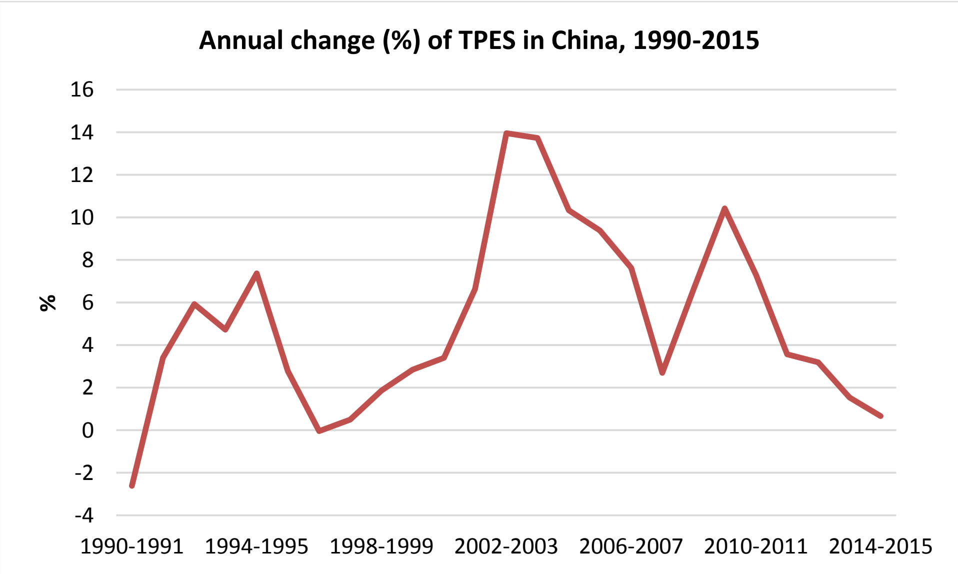

Figure 13. Annual change (%) of total primary energy supply (TPES) in China, 1990-2015.

The annual change in total primary supply (TPES) in China, presented in Figure 13, has been positive in most of the years during the studied period 1990-2015. The TPES change is decomposed into the effects identified in equation (1) above. The results for energy-related drivers TPES/FEC (efficiency of the entire energy transformation system) and FEC/GDP (energy intensity of the economy/productive system) are presented in Figure 14 and 15, respectively.

The results show that the effect of TPES/FEC has not a clear trend (Figure 14); annual contributions have either decreased or increased TPES, depending on the year. However, increasing effect is more common than decreasing effect (Figure 14; Table 4). The cumulative effect over the whole period 1990-2015 is an increasing one. The effect of FEC/GDP has been a decreasing one except one annual change (2003-2004; Figure 15). Energy intensity of the Chinese economy has decreased (Lin et al 2006; Kejun 2009), as shown also in the NDRC reports (NDRC 2015b; 2016; 2017). However, Figure 15 reveals that the annual decrease has been slowing down in the 2000s compared to those in the 1990s.

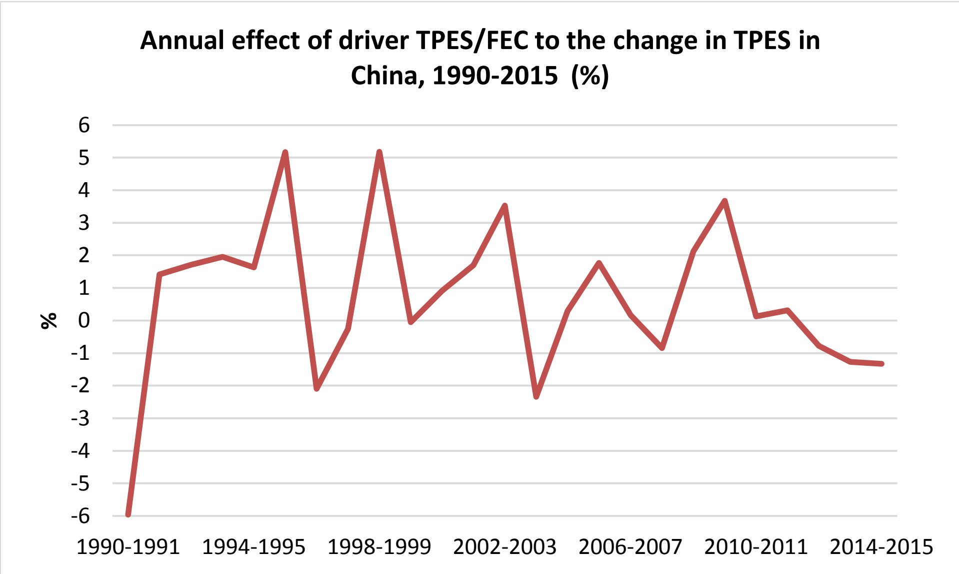

Figure 14. Annual effect of driver TPES/FEC to the change in TPES in China, 1990-2015 (%).

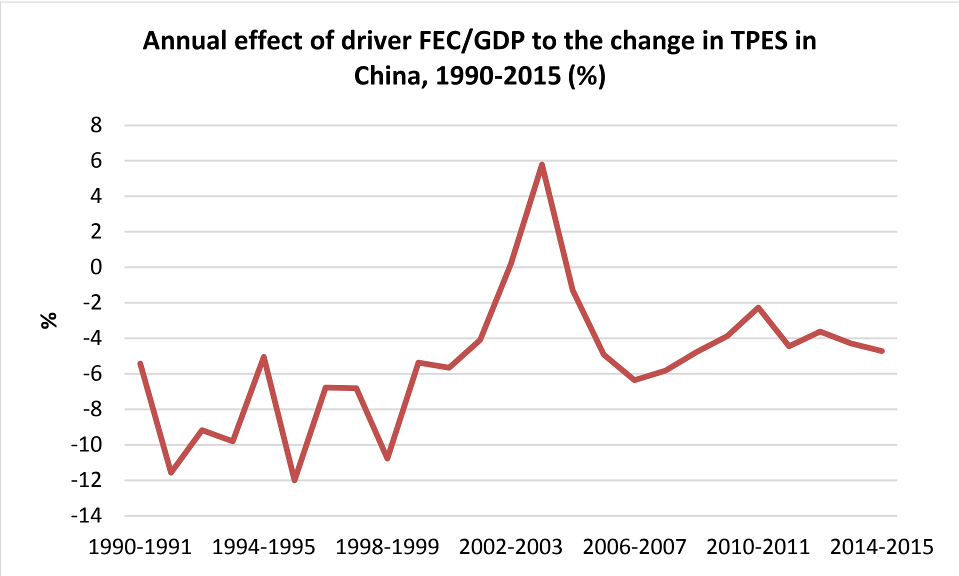

Figure 15. Annual effect of driver FEC/GDP to the change in TPES in China, 1990-2015 (%).

Table 4. Numerical values of the TPES and CO_2 emission decomposition analyses for China, 1990-2015. All figures are presented as percentage (% of the first year's absolute TPES or CO_2 value).

Period	TPES/FEC*	FEC/GDP*	GDP/POP*	POP*	TPES change*		CO_2/TPES*	TPES/FEC*	FEC/GDP*	GDP/POP*	POP*	CO_2 change*
1990-1991	-5.97	-5.42	7.43	1.35	-2.61		8.07	-6.21	-5.65	7.74	1.40	5.36
1991-1992	1.42	-11.56	12.30	1.25	3.40		0.90	1.42	-11.62	12.35	1.26	4.32
1992-1993	1.71	-9.17	12.20	1.19	5.93		2.95	1.73	-9.30	12.38	1.20	8.96
1993-1994	1.96	-9.80	11.42	1.16	4.73		-0.71	1.95	-9.77	11.38	1.16	4.01
1994-1995	1.63	-5.04	9.65	1.13	7.37		4.14	1.67	-5.14	9.84	1.15	11.66
1995-1996	5.17	-12.01	8.55	1.07	2.78		-3.26	5.09	-11.82	8.42	1.05	-0.52
1996-1997	-2.09	-6.78	7.81	1.02	-0.04		1.24	-2.11	-6.82	7.86	1.03	1.20
1997-1998	-0.25	-6.82	6.61	0.96	0.50		2.70	-0.26	-6.91	6.70	0.98	3.20
1998-1999	5.18	-10.78	6.60	0.88	1.87		-5.15	5.05	-10.50	6.43	0.85	-3.32
1999-2000	-0.05	-5.38	7.47	0.80	2.85		3.55	-0.05	-5.47	7.60	0.81	6.44
2000-2001	0.91	-5.66	7.41	0.74	3.40		1.63	0.92	-5.71	7.47	0.75	5.06
2001-2002	1.70	-4.09	8.34	0.69	6.63		1.18	1.71	-4.11	8.38	0.70	7.85
2002-2003	3.53	0.21	9.55	0.67	13.96		1.80	3.56	0.21	9.63	0.67	15.87
2003-2004	-2.34	5.79	9.65	0.63	13.74		2.65	-2.37	5.86	9.77	0.64	16.56
2004-2005	0.29	-1.30	10.72	0.62	10.33		2.95	0.29	-1.32	10.87	0.63	13.42
2005-2006	1.77	-4.91	11.95	0.59	9.40		0.91	1.78	-4.93	12.00	0.59	10.34
2006-2007	0.17	-6.35	13.28	0.54	7.64		1.71	0.17	-6.40	13.39	0.55	9.41
2007-2008	-0.84	-5.81	8.83	0.52	2.69		-0.52	-0.84	-5.80	8.80	0.52	2.16
2008-2009	2.12	-4.77	8.77	0.51	6.64		-0.31	2.12	-4.76	8.76	0.51	6.32
2009-2010	3.67	-3.88	10.12	0.51	10.42		-0.70	3.66	-3.87	10.09	0.51	9.69
2010-2011	0.13	-2.26	8.94	0.50	7.30		2.46	0.13	-2.29	9.05	0.50	9.85
2011-2012	0.31	-4.44	7.20	0.50	3.57		-1.71	0.31	-4.41	7.14	0.49	1.83
2012-2013	-0.78	-3.62	7.09	0.50	3.20		1.14	-0.78	-3.64	7.13	0.50	4.35
2013-2014	-1.27	-4.29	6.59	0.51	1.54		-1.08	-1.26	-4.27	6.56	0.51	0.45
2014-2015	-1.33	-4.72	6.20	0.51	0.67		-0.62	-1.32	-4.71	6.19	0.51	0.05
1990-2000	10.71	-93.31	100.28	12.08	29.76		34.19	26.14	-254.86	476.98	35.99	318.44
2000-2010	6.24	-18.56	54.69	3.19	45.56		15.05	12.63	-104.58	112.10	13.49	48.69
2010-2015	-1.12	-7.07	12.95	0.91	5.67		14.43	18.59	-56.07	163.27	9.45	149.67
1990-2015	22.93	-221.65	408.77	31.44	241.49		-0.76	-0.10	-25.23	48.97	3.26	26.15

The annual change in carbon dioxide emissions from fuel combustion (CO_2) in China, presented in Figure 16, has been positive in most of the years, so the CO_2 emissions have increased in China during the studied period 1990-2015. The changes have been decomposed into the effects identified in equation (2) above. The results for energy-related drivers CO_2/TPES (carbon intensity of the energy mix), TPES/FEC (efficiency of the entire energy transformation system) and FEC/GDP (energy intensity of the economy/productive system) are presented in Figures 17, 18 and 19, respectively.

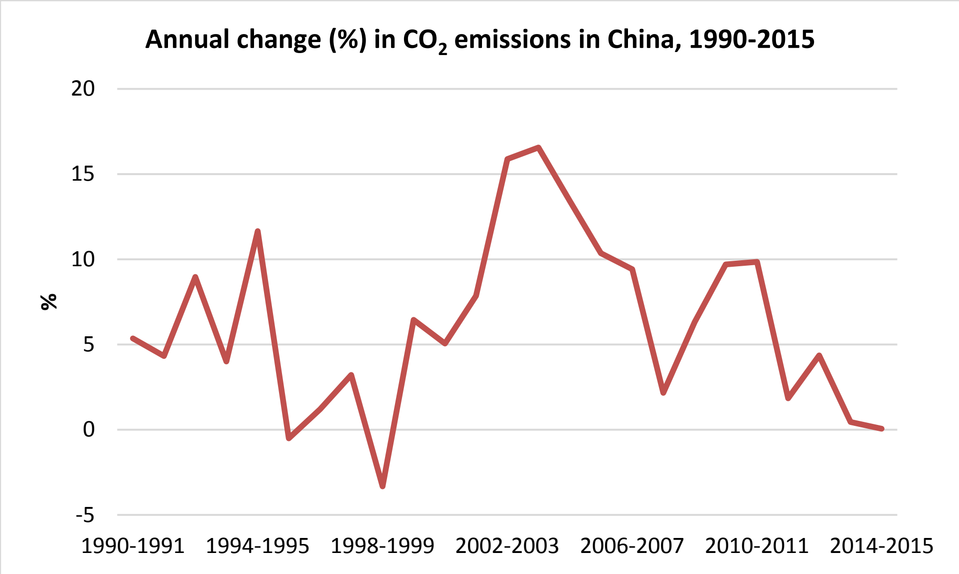

Figure 16. Annual change (%) in CO_2 emissions in China, 1990-2015.

The results show that the driver CO_2/TPES has a slightly decreasing relative trend. This reflects the fact identified also in the NDRC (2015b; 2016; 2017) that the use of low carbon primary energy sources has increased more than the use of fossil fuels. However, annual contributions to CO_2 emissions have been more increasing than decreasing ones (Figure 17; Table 4).

Similarly than in the case of TPES decomposition, the effect of TPES/FEC has not a clear trend (Figure 18). Annual contributions of TPES/FEC have either decreased or increased CO_2 emissions, depending on the year. Increasing effect is again more common than decreasing effect (Figure 18; Table 4), and the cumulative effect over the whole period 1990-2015 is an increasing one. The effect of FEC/GDP has been a decreasing one except in one annual change (Figure 19).

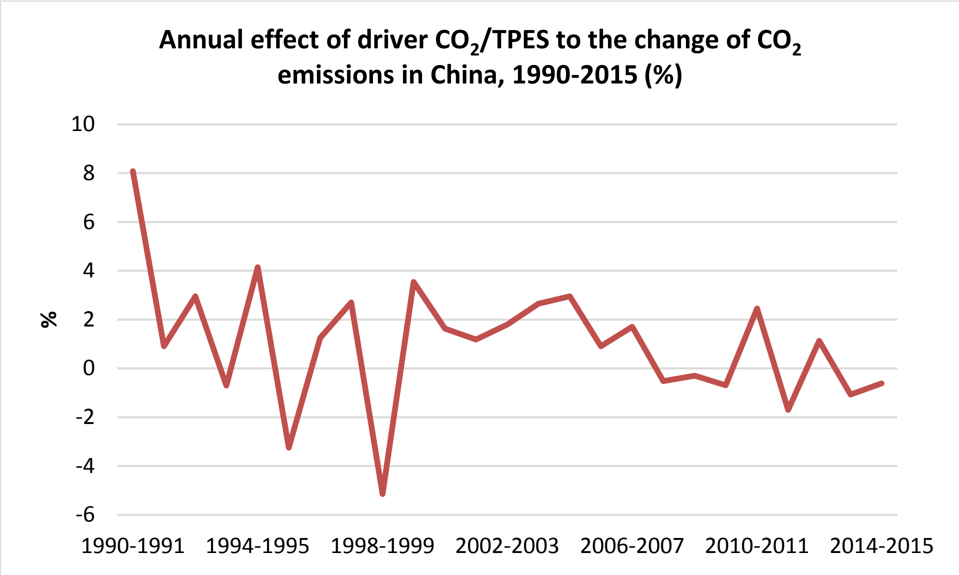

Figure 17. Annual effect of driver CO_2/TPES to the change of CO_2 emissions in China, 1990-2015 (%).

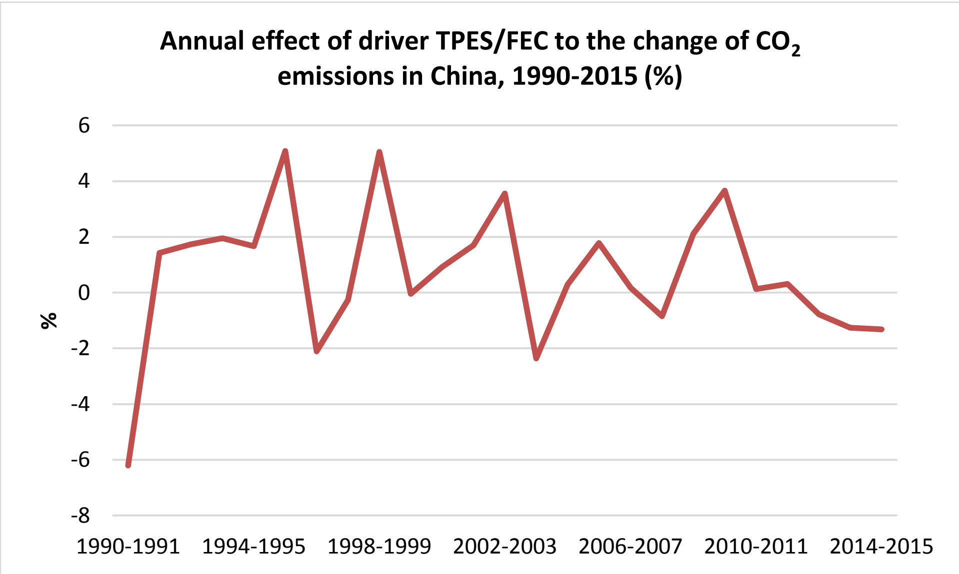

Figure 18. Annual effect of driver TPES/FEC to the change of CO_2 emissions in China, 1990-2015 (%).

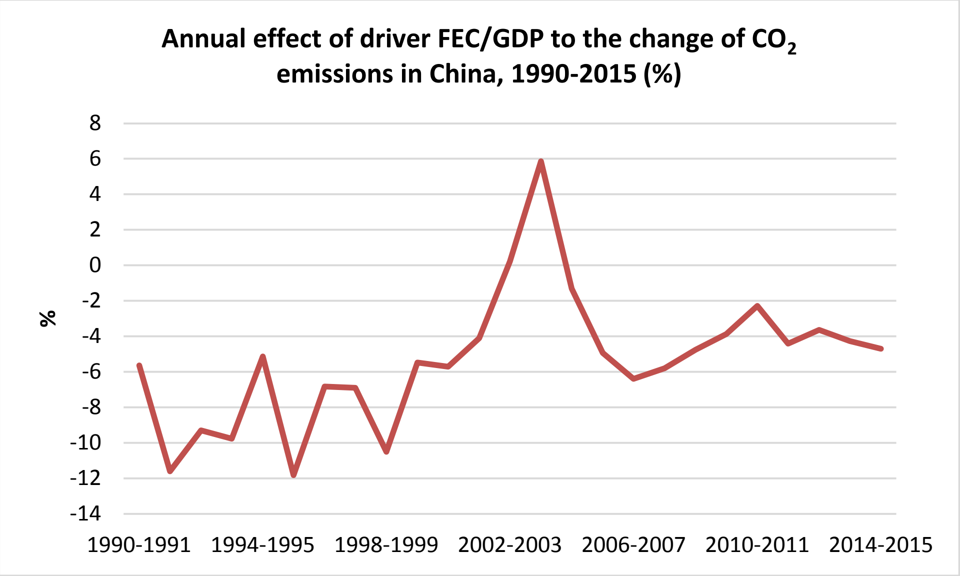

Figure 19. Annual effect of driver FEC/GDP to the change of CO_2 emissions in China, 1990-2015 (%).

Carbon intensity of the Chinese economy has decreased, according to the NDRC reports of Chinese activities addressing climate change (NDRC 2015b; 2016; 2017). However, the annual decreases in carbon intensity (CO_2/GDP) have been in the 2000s smaller than those in the 1990s (Figure 20). This observation can be made by summing up the effects of drivers, CO_2/TPES, TPES/FEC and FEC/GDP presented in Table 4 above. The sum shows increasing annual effects of CO_2/GDP to CO_2 emissions in China in the 2000s (Figure 20). The annual decrease in percentage from the previous year's absolute value seems to have a slightly increasing trend, although annual variations are still large.

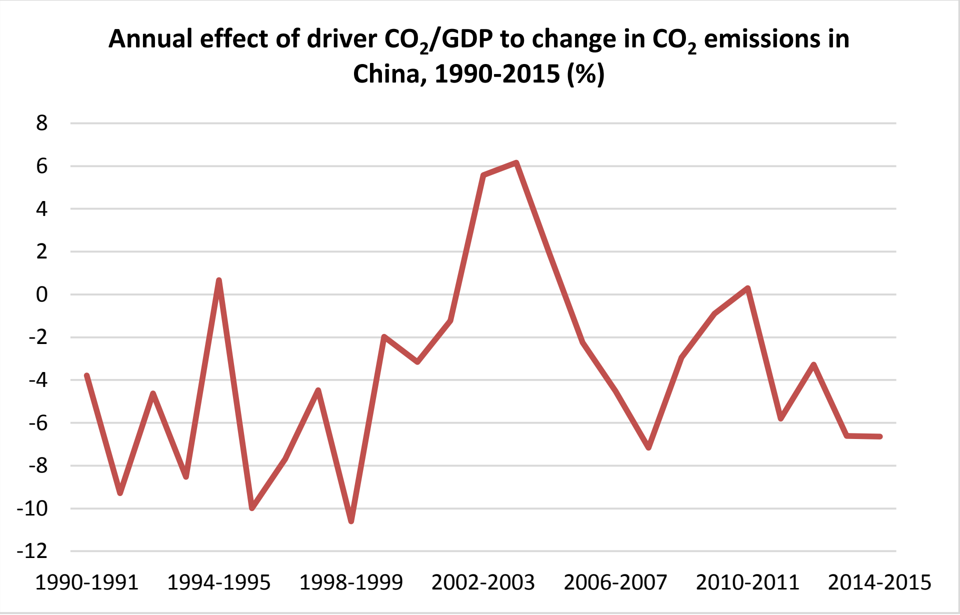

Figure 20. Annual effect of driver CO_2/GDP to the change of CO_2 emissions in China, 1990-2015 (%).

Energy efficiency scenarios for China

Comparison of historical data during 2010-2014 and old modelling results

Luukkanen et al (2015) have studied the impacts of economic structure on energy demand and related CO_2 emissions in China. They constructed three scenarios for comparison, i.e. a reference scenario (REF) which follows the recent historical trends, a policy scenario (POL) which assumes and a heavy industry scenario (IND).

The comparison of three scenarios shows that the targets of the 12th five-year plan (2011-2015) are actually considerably stringent. Reaching the energy intensity and CO_2 intensity targets is not easy even if extremely high speed of renewable energy production capacity construction has been assumed. However, the reality achieved for energy intensity and CO_2 intensity are close to the targets of the 12th FYP due to the lower rate of GDP growth, changes in economic structure, energy mix and the implemented efforts to improve energy efficiency (Table 5).

Table 5. Comparison of the 12th FYP targets, the reality and three scenarios from Luukkanen et al (2015).

Target	The12th FYP target in 2015	Situation in 2015	REF	POL	IND
GDP growth (%)	7	7.8	8.6	8.6	8.6
Energy intensity reduction (%)	-16	-18.2	-7.8	-14.6	-8.2
Reduction in CO_2 emission intensity (%)	-17	-20	-9.7	-16.7	-9.8
Share of non-fossil fuels (%)	11.4	12	11.4	12.4	11.5
Share of the service sector in the GDP (%)	47	50.5	36.0	43.4	43.4

New scenarios

To answer a research questions about energy efficiency in the main economic sectors during the period 2015-2030, three new scenarios have been constructed by using the ChinaLinda model[2]:

[2] For an introduction of the ChinaLinda model, see Luukkanen et al (2015) and Chen et al (2018). For a detailed introduction of the LINDA models, see Vehmas et al

Scenario 1 is a baseline/reference scenario where GDP follows the trend of the 12th FYP (annual growth 7.3 % during the period 2016-2020). Recently, energy intensive industries such as coal, steel, electricity production have had surplus production capacity. Many companies have reduced production, or production sites have been closed. Coal consumption decreases , because it has been estimated that the coal consumption in China has reached the peak and will decline in the future.

Scenario 2 is a policy scenario, which follows targets of the 13th FYP (annual GDP growth 6.5 % during 2016-2020, known as "the new normal"). Table 2 gives selected targets for the 13th FYP.

Table 6. Selected targets for the 13th Five Year Plan (2016-2020. Source: Central Compilation & Translation Press (2016).

Targets		2015	2020	Average annual growth (%) [accumulated]	Nature of the target
Economic development					
GDP (trillion yuan RMB)		67.7	>92.7	6.5	expected
Share of service value-added in GDP(%)		50.5	56	[5.5]	expected
Urbanization (%)	residents	56.1	60	[3.9]	expected
	registration	39.9	45	[5.1]	
Resources and environment					
Share of non-fossil fuel in energy mix (%)		12	15	[3]	constrained
Reduction of Energy consumption per unit of GDP (%)				[15]	constrained
Reduction of CO2 per unit of GDP (%)				[18]	constrained
Forestry coverage (%)		21.66	23.04	[1.38]	constrained
Forestry stock (billion m3)		15.1	16.5	[1.4]	constrained

Scenario 3 is an enhanced policy scenario assuming an even lower GDP growth rate (6.0 % during 2016-2020) and trying to make more efforts to achieve China's intended nationally determined contributions (INDC) in the Paris agreement by 2030 (see above):

- to achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early;

- to lower carbon dioxide emissions per unit of GDP by 60 % to 65 % from the 2005 level;
- to increase the share of non-fossil fuels in primary energy consumption to around 20 %; and
- To increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level.

Key results from ChinaLinda modelling

Table 7 presents the historical growth rate of value added in major economic sectors, and Table 8 presents the assumed sectoral growth rates in the same sectors in the three new scenarios (baseline scenario 1, policy scenario 2 and enhanced policy scenario 3). The growth rates are given by Chinese researchers.

Table 7. Growth rate of valued added in main economic sectors in China. 1990-2014.

Economic sector	Historical growth rate, %/a					
	1990-95	1995-98	1998-2001	2001-06	2006-10	2010-14
Agriculture	4.2	4.0	2.7	4.4	4.4	4.2
Industry	17.7	10.9	9.0	11.7	11.4	8.3
Transportation, communication	10.5	10.3	9.8	9.7	8.2	7.3
Commercial	9.8	8.1	8.9	11.7	13.9	9.1
Construction	14.6	7.1	5.6	12.4	14.4	9.5
Others	11.6	5.8	5.8	11.6	9.4	8.4
Total	12.2	9.1	5.3	12.4	11.0	8.1

Table 8. Assumed growth rates (%) of value added in major economic sectors in the three ChinaLinda scenarios.

Economic sector	Scenario 1 (baseline)			Scenario 2 (policy)			Scenario 3 (enhanced policy)		
	2014-20	2020-25	2025-30	2014-20	2020-25	2025-30	2014-20	2020-25	2025-30
Agriculture	4.0	3.0	3.0	4.0	3.0	3.0	4.0	3.0	3.0
Industry	7.0	6.0	6.0	6.5	6.0	5.5	6.0	5.5	5.0
Transportation, communi-cation	6.0	5.o	5.0	6.0	5.0	5.0	6.0	5.0	5.0
Commercial	9.0	8.0	8.0	8.0	7.0	6.0	7.0	6.0	5.0
Construction	14.0	13.0	13.0	9.0	8.5	8.0	7.0	6.0	5.0
Others	6.0	5.0%	5.0%	6.0	5.0	5.0	6.0	5.0	5.0
Total	7.3	6.5	6.8	6.5	5.9	5.5	6.0	5.3	4.9

An interesting observation is that the economic growth rate decreases when policies to increase energy efficiency and to reduce CO_2 emissions are increased. Thus, economic growth is the slowest in the enhanced policy scenario 3. Tables 9-11 include the assumed change rates of electricity and fuel intensities in different economic sectors for the three scenarios.

Table 9. Assumed electricity and fuel intensities in the baseline scenario 1.

Annual percentual changes									
Electricity intensity ktoe/100million CNY				Fill in the future annual growth rates (%) in the yellow cells					
	1990-95	1995-98	1998-2001	2001-06	2006-09	2009-14	2014-20	2020-25	2025-30
Agriculture	2 %	-10 %	4 %	3 %	0 %	-3 %	-3 %	-4 %	-4 %
Industry	-7 %	-7 %	0 %	2 %	-3 %	0 %	-6 %	-7 %	-7 %
Commercial	10 %	10 %	2 %	1 %	-3 %	2 %	-5 %	-6 %	-6 %
Transpotration	1 %	4 %	-5 %	-1 %	2 %	3 %	-3 %	-4 %	-4 %
Construction	4 %	-5 %	-8 %	0 %	1 %	1 %	-11 %	-12 %	-12 %
Residential electricity use（Urban）(	16 %	15 %	5 %	15 %	12 %	7 %	6 %	5 %	5 %
Residential electricity use（Rural） (	16 %	0 %	13 %	17 %	15 %	14 %	6 %	5 %	5 %
Others	-8 %	21 %	-4 %	6 %	-1 %	2 %	6 %	5 %	5 %
Import (not intensity)	-20 %	-70 %	373 %	25 %	4 %	2 %	10 %	10 %	10 %
Export (not intensity)	132 %	6 %	12 %	4 %	12 %	1 %	10 %	10 %	10 %
Annual percentual changes									
Energy (fuel use) intensity changes ktoe/100million. CNY				Fill in the future annual growth rates (%) in the yellow cells					
	1990-95	1995-98	1998-2001	2001-06	2006-10	2010-14	2014-20	2020-25	2025-30
Agriculture	-1 %	-3 %	-1 %	1 %	-1 %	2 %	-3 %	-4 %	-4 %
Industry	-13 %	-11 %	-9 %	-3 %	-7 %	-1 %	-6 %	-7 %	-7 %
Commercial	-3 %	-3 %	-10 %	-1 %	-8 %	5 %	-5 %	-6 %	-6 %
Residential use（Urban）(not intensit	-5 %	-9 %	2 %	9 %	6 %	8 %	6 %	5 %	5 %
Residential use（Rural）(not intensity	0 %	-9 %	-1 %	8 %	4 %	5 %	6 %	5 %	5 %
Construction	-18 %	11 %	0 %	-1 %	-1 %	-6 %	-11 %	-12 %	-12 %
Transportation	-5 %	6 %	-3 %	3 %	-2 %	1 %	-3 %	-4 %	-4 %
Others	-4 %	-14 %	-6 %	-4 %	-6 %	2 %	6 %	5 %	5 %

Table 10. Assumed electricity and fuel intensities in the policy scenario 2.

Annual percentual changes									
Electricity intensity ktoe/100million CNY				Fill in the future annual growth rates (%) in the yellow cells					
	1990-95	1995-98	1998-2001	2001-06	2006-09	2009-14	2014-20	2020-25	2025-30
Agriculture	2 %	-10 %	4 %	3 %	0 %	-3 %	-3 %	-4 %	-5 %
Industry	-7 %	-7 %	0 %	2 %	-3 %	0 %	-7 %	-9 %	-11 %
Commercial	10 %	10 %	2 %	1 %	-3 %	2 %	-6 %	-7 %	-8 %
Transpotration	1 %	4 %	-5 %	-1 %	2 %	3 %	-4 %	-5 %	-6 %
Construction	4 %	-5 %	-8 %	0 %	1 %	1 %	-12 %	-14 %	-16 %
Residential electricity use（Urban）(	16 %	15 %	5 %	15 %	12 %	7 %	6 %	5 %	5 %
Residential electricity use（Rural） (	16 %	0 %	13 %	17 %	15 %	14 %	6 %	5 %	5 %
Others	-8 %	21 %	-4 %	6 %	-1 %	2 %	6 %	5 %	5 %
Import (not intensity)	-20 %	-70 %	373 %	25 %	4 %	2 %	10 %	10 %	10 %
Export (not intensity)	132 %	6 %	12 %	4 %	12 %	1 %	10 %	10 %	10 %

Annual percentual changes									
Energy (fuel use) intensity changes ktoe/100million. CNY				Fill in the future annual growth rates (%) in the yellow cells					
	1990-95	1995-98	1998-2001	2001-06	2006-10	2010-14	2014-20	2020-25	2025-30
Agriculture	-1 %	-3 %	-1 %	1 %	-1 %	2 %	-3 %	-4 %	-5 %
Industry	-13 %	-11 %	-9 %	-3 %	-7 %	-1 %	-8 %	-10 %	-12 %
Commercial	-3 %	-3 %	-10 %	-1 %	-8 %	5 %	-6 %	-7 %	-8 %
Residential use（Urban）(not intensit	-5 %	-9 %	2 %	9 %	6 %	8 %	6 %	5 %	5 %
Residential use（Rural）(not intensity	0 %	-9 %	-1 %	8 %	4 %	5 %	6 %	5 %	5 %
Construction	-18 %	11 %	0 %	-1 %	-1 %	-6 %	-12 %	-14 %	-16 %
Transportation	-5 %	6 %	-3 %	3 %	-2 %	1 %	-4 %	-5 %	-6 %
Others	-4 %	-14 %	-6 %	-4 %	-6 %	2 %	6 %	5 %	5 %

Table 11. Assumed electricity and fuel intensities in the enhanced policy scenario 3.

Annual percentual changes									
Electricity intensity ktoe/100million CNY				Fill in the future annual growth rates (%) in the yellow cells					
	1990-95	1995-98	1998-2001	2001-06	2006-09	2009-14	2014-20	2020-25	2025-30
Agriculture	2 %	-10 %	4 %	3 %	0 %	-3 %	-4 %	-5 %	-5 %
Industry	-7 %	-7 %	0 %	2 %	-3 %	0 %	-8 %	-9 %	-10 %
Commercial	10 %	10 %	2 %	1 %	-3 %	2 %	-6 %	-7 %	-8 %
Transpotration	1 %	4 %	-5 %	-1 %	2 %	3 %	-4 %	-5 %	-6 %
Construction	4 %	-5 %	-8 %	0 %	1 %	1 %	-13 %	-14 %	-15 %
Residential electricity use（Urban）(	16 %	15 %	5 %	15 %	12 %	7 %	6 %	5 %	5 %
Residential electricity use（Rural） (	16 %	0 %	13 %	17 %	15 %	14 %	6 %	5 %	5 %
Others	-8 %	21 %	-4 %	6 %	-1 %	2 %	6 %	5 %	5 %
Import (not intensity)	-20 %	-70 %	373 %	25 %	4 %	2 %	10 %	10 %	10 %
Export (not intensity)	132 %	6 %	12 %	4 %	12 %	1 %	10 %	10 %	10 %

Annual percentual changes									
Energy (fuel use) intensity changes ktoe/100million. CNY				Fill in the future annual growth rates (%) in the yellow cells					
	1990-95	1995-98	1998-2001	2001-06	2006-10	2010-14	2014-20	2020-25	2025-30
Agriculture	-1 %	-3 %	-1 %	1 %	-1 %	2 %	-3 %	-4 %	-4 %
Industry	-13 %	-11 %	-9 %	-3 %	-7 %	-1 %	-9 %	-10 %	-11 %
Commercial	-3 %	-3 %	-10 %	-1 %	-8 %	5 %	-6 %	-7 %	-8 %
Residential use（Urban）(not intensit	-5 %	-9 %	2 %	9 %	6 %	8 %	6 %	5 %	5 %
Residential use（Rural）(not intensity	0 %	-9 %	-1 %	8 %	4 %	5 %	6 %	5 %	5 %
Construction	-18 %	11 %	0 %	-1 %	-1 %	-6 %	-13 %	-14 %	-15 %
Transportation	-5 %	6 %	-3 %	3 %	-2 %	1 %	-4 %	-5 %	-6 %
Others	-4 %	-14 %	-6 %	-4 %	-6 %	2 %	6 %	5 %	5 %

The differences between the three scenarios in terms of electricity and fuel intensities are quite modest. For example, the average annual change rates for industry in the baseline scenario 1, in the policy scenario 2 and in the enhanced policy scenario 3 for the period 2025-2030 are -7 %, -11 % and -10 %, respectively. Especially the difference between the two policy scenarios 2 and 3 are small. It is interesting that the Chinese researchers have assumed a slower decrease in industrial electricity intensity for the enhanced policy scenario than for the policy scenario. The situation is similar for most of the economic sectors and for the entire national Chinese economy as well.

The assumptions on economic growth have variation between the three scenarios; growth is the fastest in the baseline scenario 1 and the slowest in the enhanced policy scenario 3 (Table 8). The policy scenario 2 falls in between. These assumptions cause differences in all the results dealing with electricity consumption (Figures 21-23), final energy consumption (Figures 24-26), fuel use (Figures 27-29), and CO_2 emissions from fossil fuel combustion (Figures 30-32).

Figures 21-23 show the results in terms of electricity consumption per sector in Chin main the baseline scenario 1 (Figure 21), in the policy scenario 2 (Figure 22) and in the enhanced policy scenario 3 (Figure 23). Electricity consumption continues growing in the baseline scenario 1 (Figure 21), grows a few years after the base year 2014 and then starts to decrease in policy scenario 2 (Figure 22), and starts to decrease after the base year 2014 in enhanced policy scenario 3 (Figure 23).

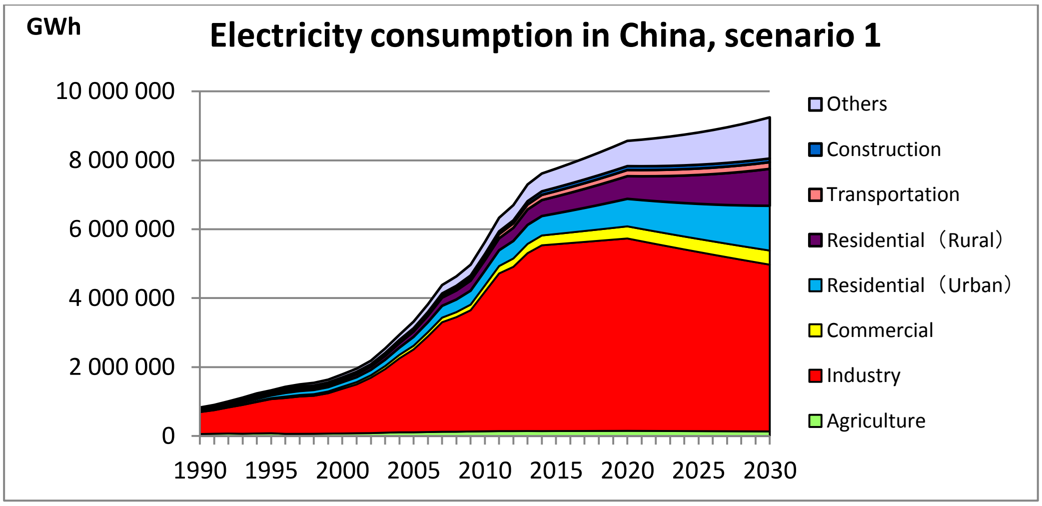

Figure 21. Sectoral electricity consumption in China 1990-2030, scenario 1 (baseline).

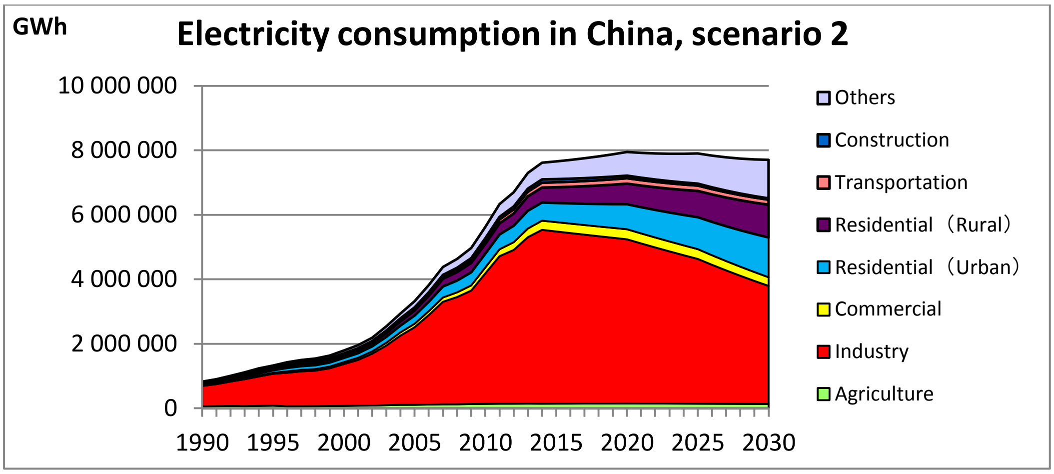

Figure 22. Sectoral electricity consumption in China 1990-2030, scenario 2 (policy).

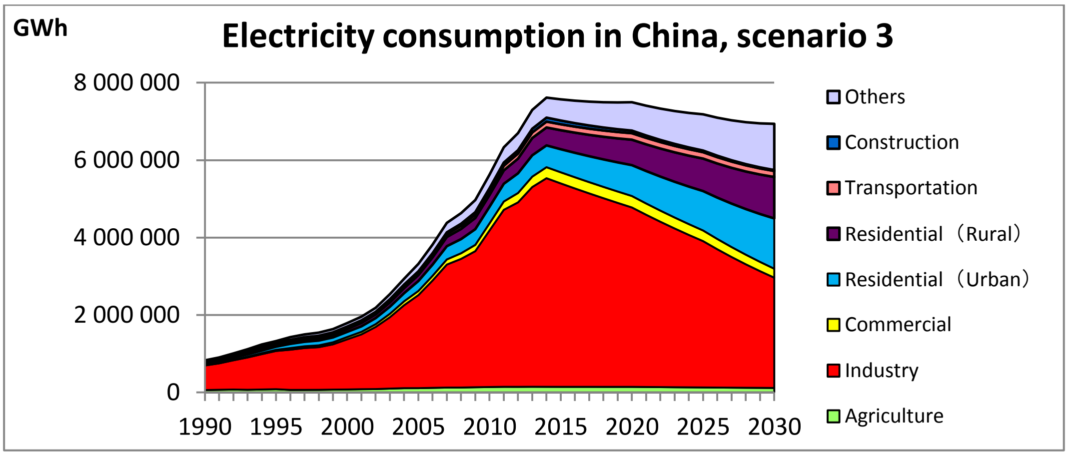

Figure 23. Sectoral electricity consumption in China 1990-2030, scenario 3 (enhanced policy).

Figures 24-26 describe the results in terms of sectoral final energy consumption in the baseline scenario 1 (Figure 24), in the policy scenario 2 (Figure 25) and in the enhanced policy scenario 3 (Figure 26). Sectoral final energy continues growing in the baseline scenario1 (Figure 24). Growth in industry, however, decreases. In the policy scenario 2, the decrease of final energy consumption in industry is faster and thus the total growth remains quite a modest one (Figure 25). In the enhanced policy scenario, final energy consumption stagnates to the level of the base year 2014 but slightly incre3ases during the last five-year period 2025-2040 (Figure 26).

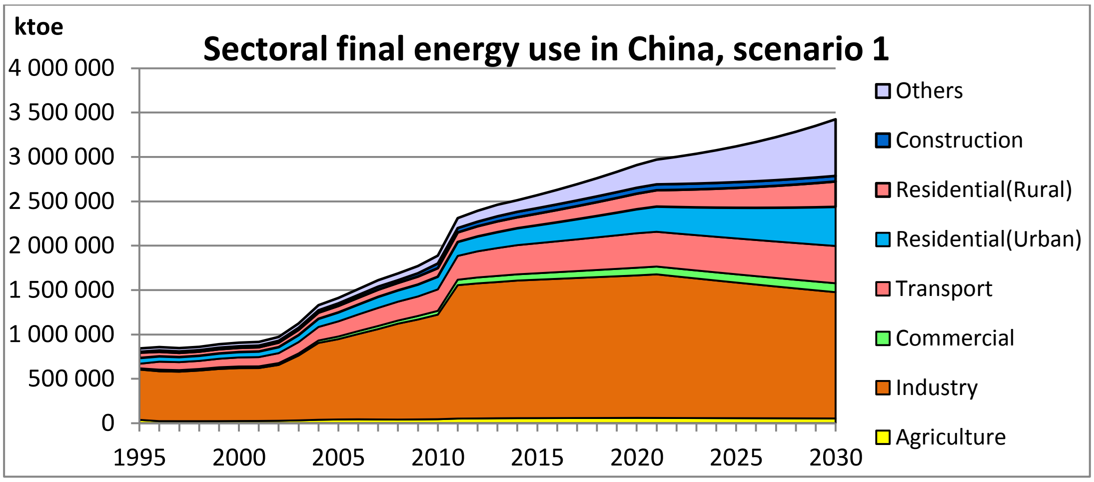

Figure 24. Sectoral final energy consumption in China 1990-2030, scenario 1 (baseline).

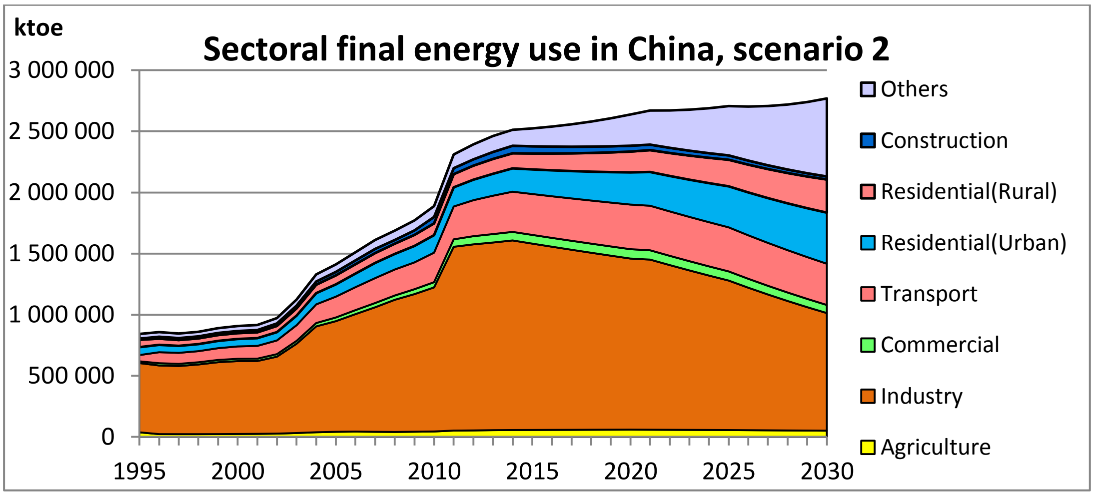

Figure 25. Sectoral final energy consumption in China 1990-2030, scenario 2 (policy).

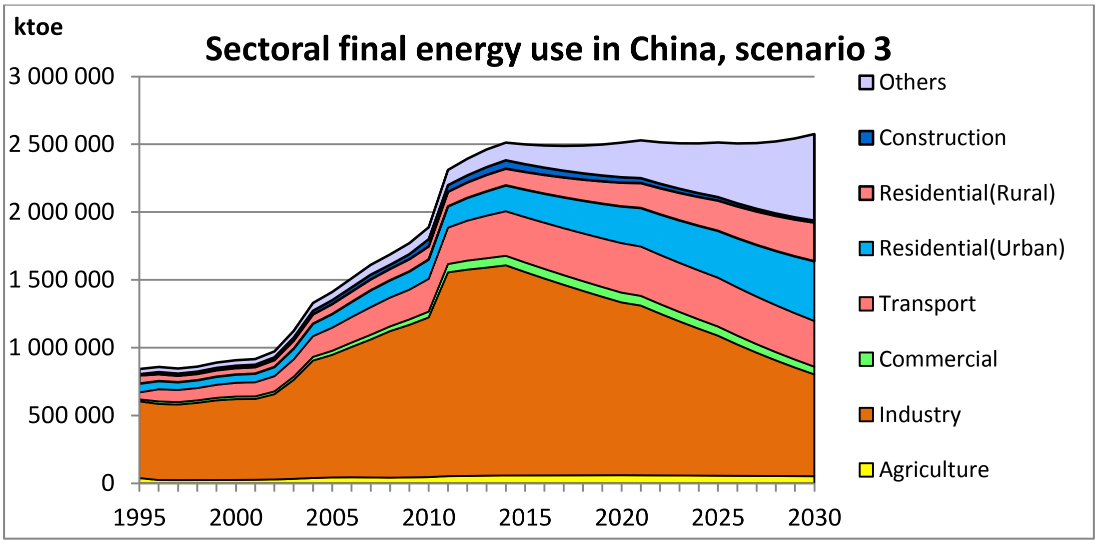

Figure 26. Sectoral final energy consumption in China 1990-2030, scenario 3 (enhanced policy).

Figures 27-29 describe the modelling results in terms of fossil fuel use in the baseline scenario 1 (Figure 27), in the policy scenario 2 (Figure 28) and in the enhanced policy scenario 3 (Figure 29). Use of the fossil fuels, especially the use of coal, increases in all scenarios. Increase in coal use is the largest in the baseline scenario 1 (Figure 27), and the policy scenario 2 and enhanced policy scenario 3 do not have significant differences in the use of fossil fuels (Figures 28 and 29).

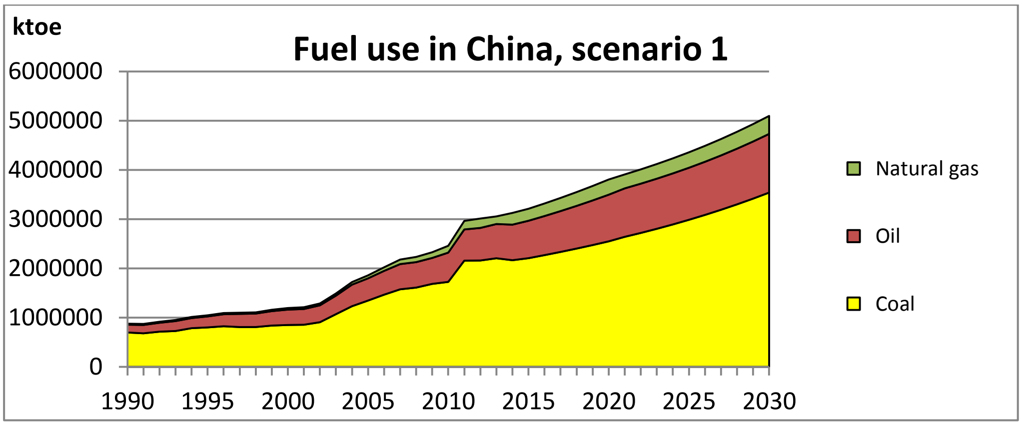

Figure 27. Fossil fuel use in China 1990-2030, scenario 1 (baseline).

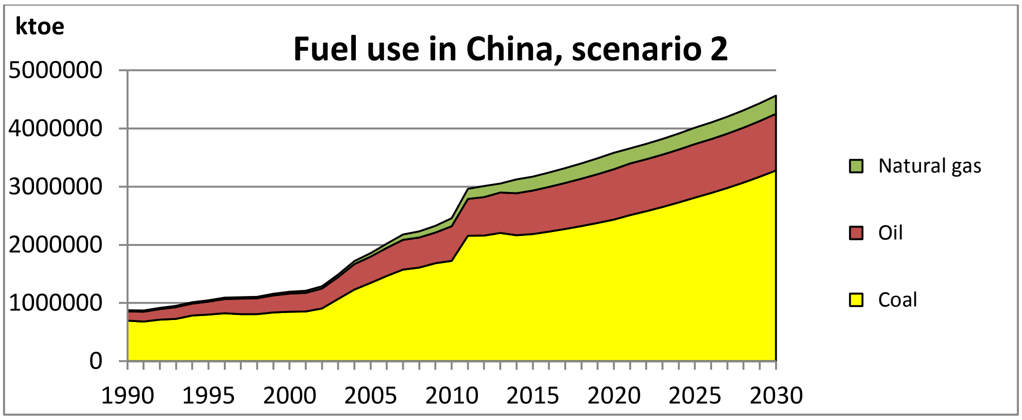

Figure 28. Sectoral final energy consumption in China 1990-2030, scenario 2 (policy).

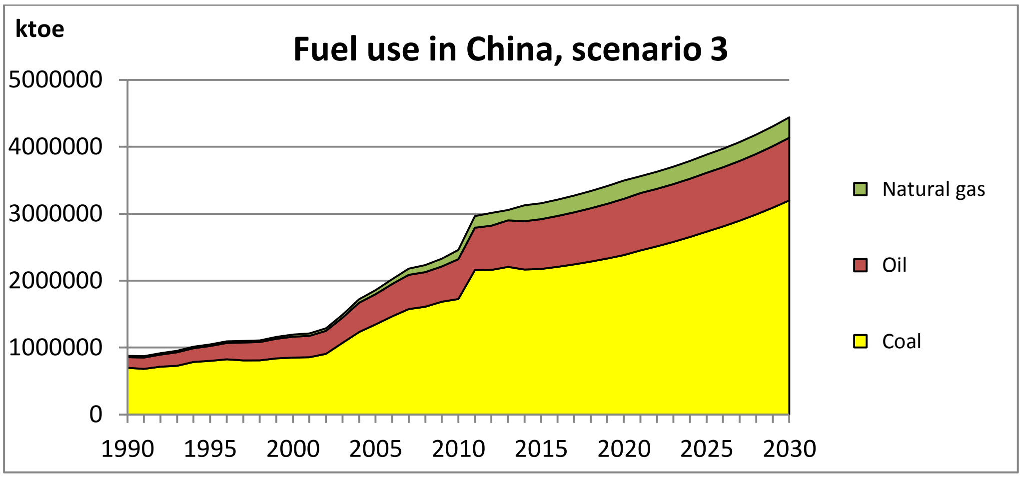

Figure 29. Sectoral final energy consumption in China 1990-2030, scenario 3 (enhanced policy).

Finally, Figures 30-32 describe the ChinaLinda modelling results in terms of carbon dioxide (CO_2) emissions from fuel combustion in the baseline scenario 1 (Figure 30), in the policy scenario 2 (Figure 31) and in the enhanced policy scenario 3 (Figure 32). Differences between scenarios in terms of CO_2 emission figures (Figures 30-32) are similar than the differences in the use of fossil fuels (Figures 27-29).

Quite modest differences between the major assumptions (economic growth in different sectors and change in electricity and fuel intensities in the different sectors) cause differences in the three scenarios in terms of the output variables, such as electricity consumption, final energy consumption, use of fossil fuels, and related CO_2 emissions. The assumptions made by the Chinese researchers in the case of enhanced policy scenario 3 are interesting, because the enhanced policy seems to affect more to economic growth than in the electricity and fu3el intensities. However, the ChinaLInda model as the LINDA models in general, are accounting models where the assumptions made for the input are directly reflected to the output. This is clearly seen when the input and output variables are compared to each other.

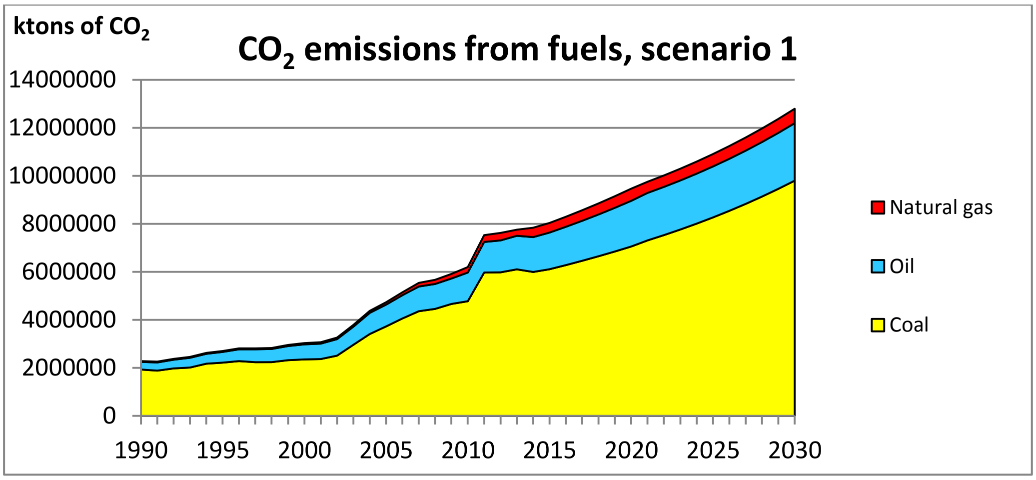

Figure 30. CO_2 emissions from fossil fuel combustion in China 1990-2030, scenario 1 (baseline).

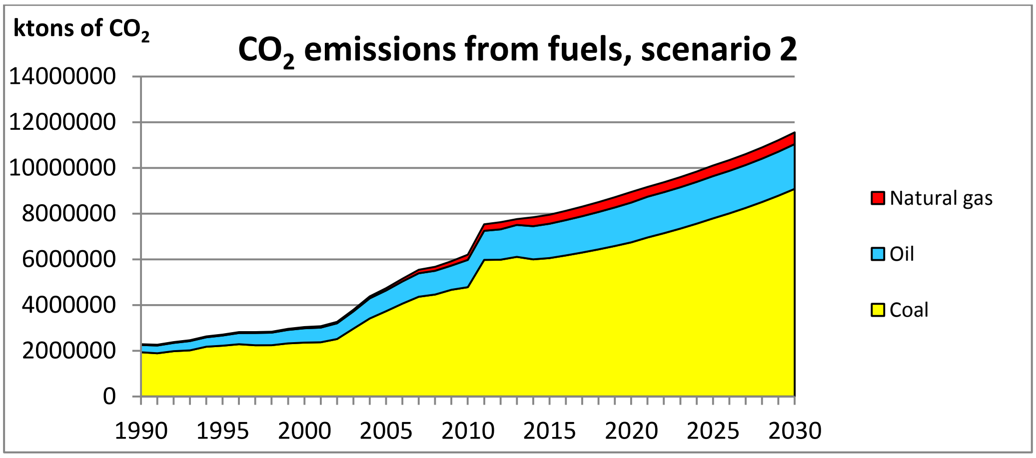

Figure 31. CO_2 emissions from fossil fuel combustion in China 1990-2030, scenario 2 (policy).

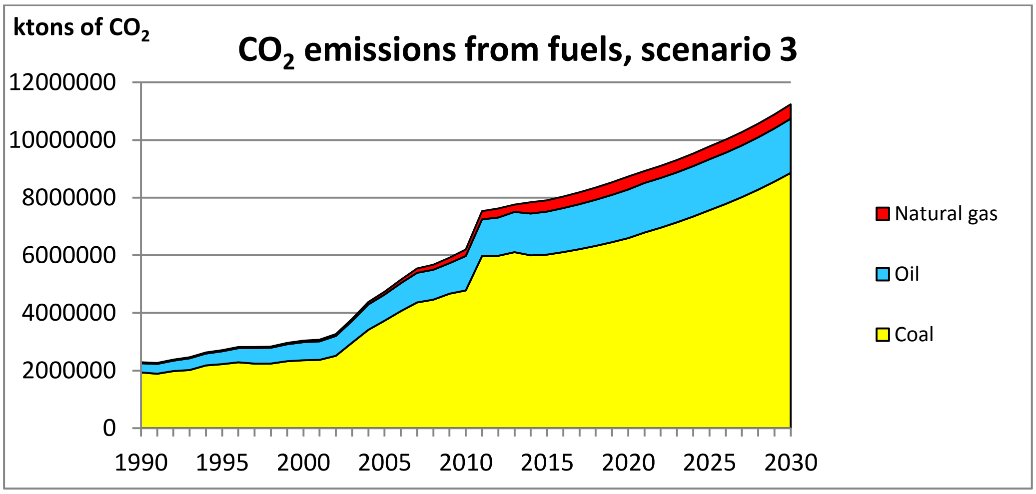

Figure 32. CO_2 emissions from fossil fuel combustion in China 1990-2030, scenario 1 (enhanced policy).

Conclusions

In this report, energy use, energy efficiency as well as energy efficiency policies and measures in China have been described and analyzed. Energy use, especially the use of coal, and related environmental impacts are huge in China, which is nowadays the largest coal user and emitter of carbon dioxide emissions (CO_2) in the World. Environmental impacts of energy use and energy security are major reasons for improving energy efficiency in China.

In the five-year plans (FYP), the Chinese Government has set quantitative targets for energy intensity of the economy, CO_2 emissions per unit of GDP, and for the share of renewable sources in the energy mix, for example. These targets are set every five years, and distributed to different sectors in the centrally planned market economy of China. The current 13th FYP includes targets for the years 2016-2020, 15 % reduction in energy intensity, 18 % reduction in CO_2 emissions per unit of GDP, and increasing the share of non-fossil energy sources up to 3 % of the energy mix. A set of new policies and measures have been introduced and implemented, to ensure meeting of these targets. The detailed activities related to energy efficiency can be found in annual reports provided by the National Development and Reform Commission (NFRC). One of the most recent activities is the national emissions trading scheme for greenhouse gas emissions, which was launched in December 2017 after a pilot phase introduced already in the 12th FYP.

The effectiveness of the Chinese energy efficiency policies can be seen in the rapid decrease in energy and carbon intensities of the Chinese economy. Because of the fast economic growth and the coal-dominated energy mix, however, the primary energy use and CO_2 emissions of China have not decreased, only the speed of increase has slightly slowed down. The role of coal is still dominant in the energy mix, and economic growth counterbalances the decreasing effect to energy use and CO_2 emissions caused by decreasing energy intensity and the slight introduction of low-carbon energy sources.

Quite modest differences between the major assumptions (economic growth in different sectors and change in electricity and fuel intensities in the different sectors) cause visible differences in the three scenarios in terms of the output variables, such as electricity consumption, final energy consumption, use of fossil fuels, and related CO_2 emissions. The assumptions made by the Chinese researchers in the case of enhanced policy scenario 3 are interesting, because the enhanced policy seems to affect more to the assumptions on economic growth than to the assumptions on electricity and fuel intensities. However, the ChinaLInda model as the LINDA models in general, are accounting models where the assumptions made for the input are directly reflected to the output. This is clearly seen when the input and output variables are compared to each other.

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