European Futures for Energy Efficiency

649342 EUFORIE

Provincial energy efficiency analysis in China

WP8 Deliverable D8.4

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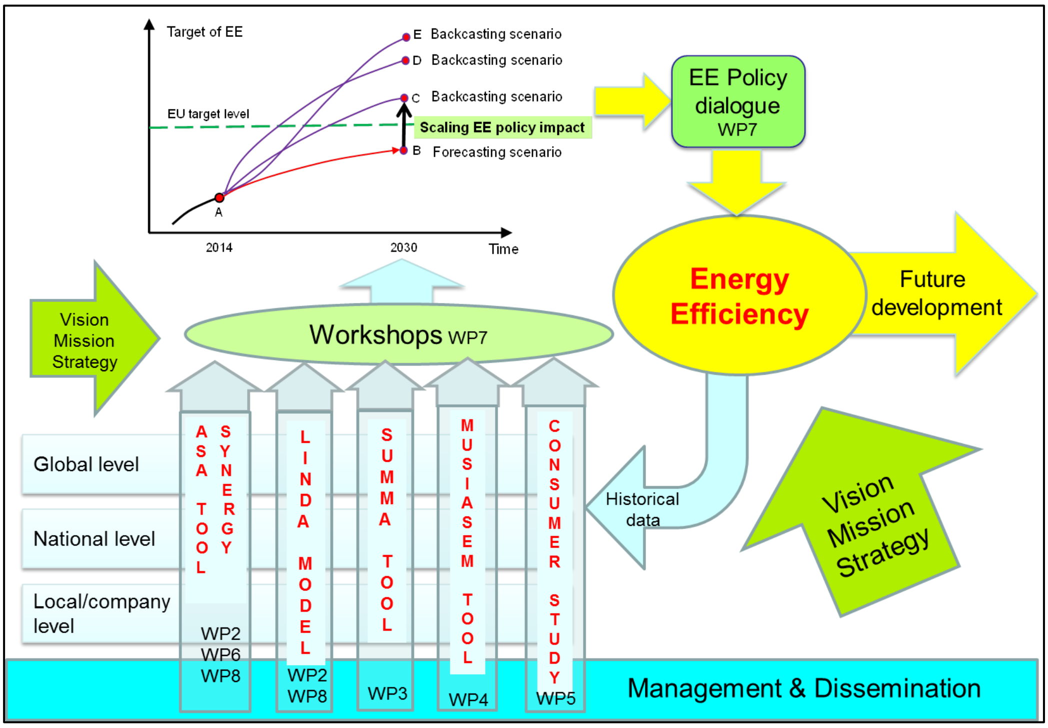
The EUFORIE project

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

The purpose of this deliverable is to analyse energy efficiency in China at the provincial level. The goal is to find out how the energy efficiency related drivers have affected energy use and related carbon dioxide emissions in different Chinese provinces and other administrative regions.

To reach the goal, an incremental chained two-factor decomposition analysis has been carried out for analyzing the effects of change in indicators of energy efficiency and other drivers of total primary energy supply (TPES) and carbon dioxide emissions, identified in extended Kaya type identities, from fuel combustion (CO_2) in 20 Chinese provinces and other administrative regions.

$$TPES = \frac{TPES}{FEC} \times \frac{FEC}{GRP} \times \frac{GRP}{EMP} \times \frac{EMP}{POP} POP$$

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GRP} \times \frac{GRP}{EMP} \times \frac{EMP}{POP} \times POP$$

where TPES is total primary energy use, FEC is final energy consumption, GRP is gross regional product in constant/real process, EMP is the amount of employed persons and POP is the amount of population.

Four selected regions (Guangdong, Hebei, Shandong and Tianjin) with different profiles in terms of CO_2 emissions, economic structure and urban/rural population have been looked at in more detail to interpret the decomposition results.

The data has been gathered from Chinese national energy statistics provided by the National Bureau of Statistics (NBS) and regional statistical yearbooks provided by the regional administration. The collected data includes annual CO_2 emissions, total primary energy use, final energy consumption, gross regional product (GRP) and amount of population from the years 2005-2014. The regional statistics are available mostly in Chinese, so this deliverable includes a description about data availability and problems of data collection and interpretation of Chinese statistics (see Annex 1).

The most important driver of TPES and CO_2 emissions with a decreasing effect in the period 2005-2014 has been "energy intensity" (FEC/GRP), which has decreased TPES and CO_2 emissions in all administrative regions in China, except the Xinjiang autonomous region. The driver "carbon intensity" (CO_2/TPES) has increased CO_2 emissions in the provinces of Anhui, Guangdong, Jilin, Shaanxi and Shandong, and in the autonomous regions of Inner Mongolia and Xinjiang. In the other 13 Chinese administrative regions, the driver CO_2/TPES has decreased CO_2 emissions.

The driver (TPES/FEC), the ratio between primary and final energy use, describes efficiency of energy production, transfer, and distribution – the smaller the ratio, the better the efficiency. Usefulness of the TPES/FEC ratio suffers from statistical practices of measuring some energy sources in terms of primary energy, such as wind, solar, geothermal and nuclear. However, from the point of view of decomposition analysis, this driver, "efficiency of the energy transformation system", is relevant because it describes change in the primary energy mix and change in the efficiency of energy

production. The driver TPES/FEC has had a relatively small effect to total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2) in almost all Chinese regions. A decreasing effect to both TPES and CO_2 in the province of Shaanxi, and an increasing effect to both TPES and CO_2 in the province of Shanxi can be mentioned.

The driver “energy intensity” (FEC /GRP) has had an increasing effect to both total primary energy use and CO_2 emissions in all provinces. A decreasing effect of this driver is a surprise in Chinese provinces and other administrative regions. There is a couple of annual decreasing effects in the results for the province of Shanxi and the autonomous region Inner Mongolia during the studied period 2004-2014, they are for both total primary energy use and CO_2 emissions.

The drivers “labour productivity” (GRP/EMP), “employment” (EMP/POP) and “population” have usually increased both TPES and CO_2 in all the studied Chinese provinces and other administrative regions. GRP/EMP has been the most important driver with an increasing effect to TPES and CO_2.

A major finding is that despite of a significant decreasing effect of energy efficiency (decreasing energy intensity), total primary energy supply and CO_2 emissions have increased in most of the Chinese regions because other drivers such as economic growth has had a larger increasing effect. However, the rate of increasing has been lower in the recent years, especially in urban regions such as the municipalities of Beijing and Tianjin.

The results of decomposition analysis of total primary energy use and CO_2 emissions in the 20 Chinese provinces and other administrative regions are presented as Figures for the period 2005-2014 in the second chapter “Decomposition analysis of total primary energy supply and CO_2 emissions in China at the regional level” of this deliverable. Detailed annual results are available for total primary energy use in Annex 2 and for CO_2 emissions in Annex 3 of this deliverable.

The results show that the differences between Chinese provinces and other administrative regions are large in a similar way than the differences between EU Member states. The results from the decomposition analyses may be useful for researchers and all stakeholder groups interested in the energy performance of Chinese provinces and other administrative regions, as well as those interested in the comparative analysis by using the decomposition method.

The EUFORIE project has also produced a comparative analysis between China and the European Union. These analyses are available in other EUFORIE deliverables mentioned in the list of references (Vehmas 2019; Giampietro et al 2019). National level analysis of China is available in Chen et al (2019a), and analyses for sectoral level (Chen et al 2019b), and analysis of the building/residential sector is also available (Panula-Ontto et al 2019).

Tasks of this deliverable related to WP8

This deliverable covers the following EUFORIE WP8 (Chinese energy efficiency and comparison of European/Chinese energy policies) tasks:

- Task 8.4: “Provincial level analysis”
- The deliverable provides also input for Task 8.6: “Comparison EU-China”.

Contents

Abbreviations

Abbreviation	Explanation
CO_2	Carbon dioxide (emissions from fuel combustion)
EMP	Employment, number of employed people
FEC	Final energy consumption
GDP	Gross domestic product
GRP	Gross regional product
IEA	International Energy Agency
IMF	International Monetary Fund
Mtoe	Million tonnes of oil equivalent
Mton	Million tonnes
NBS	National Bureau of Statistics, China
POP	Population, number of population
RMB	Renmimbi, currency of China (unit CNY, Chinese yuan)
SCE	Standard coal equivalent
tce	Tonnes of coal equivalent
toe	Tonnes of oil equivalent
TPES	Total primary energy supply
USD, US$	United States dollars

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Goals of this deliverable

The goal of this deliverable is to find out, how change in energy efficiency has influenced total primary energy supply and CO_2 emissions in China at the regional level. This has been done by collecting data from Chinese provinces and other administrative regions for incremental decomposition analysis, which identifies the effects of energy efficiency and other drivers to annual changes in total primary energy supply and CO_2 emissions.

Introduction: Chinese provinces and other administrative regions

Regional administrative division of People's Republic of China includes 23 provinces, five autonomous regions with a particular ethnic minority, four municipalities, two special administrative regions (Hong Kong and Macau) and one claimed province (Taiwan), altogether 35 administrative regions (Figure 1).

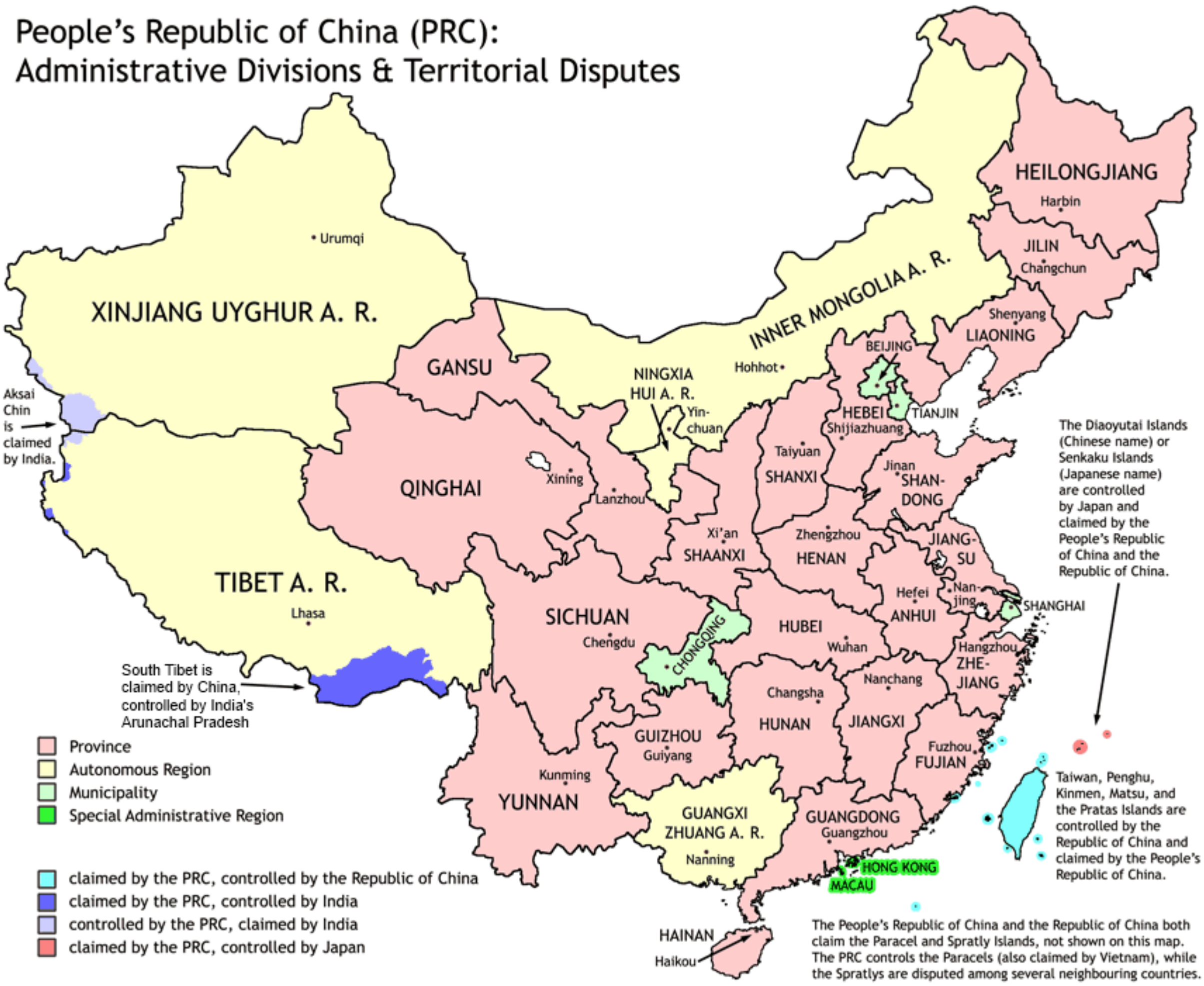

Figure 1. Administrative regions in China. Source: Vikivoyage (2017).

The size of Chinese regions varies considerably in terms of geographical area (Figure 1), number of population (Figure 2) and economic activity (Figure 3). In the following, two different decomposition analyses, one of total primary energy supply (TPES) and one of carbon dioxide emissions from fuel combustion (CO_2) will be carried out for 20 administrative regions of China with sufficient data availability. The purpose of the decomposition analysis is to identify the significance of a set of pre-defined drivers to change in the decomposed variables TPES and CO_2. Especially the effects of energy efficiency related drivers is on the focus in this analysis. After presenting the results from the decomposition analyses, four regions are taken into closer consideration in order to deepen the interpretation of the decomposition results.

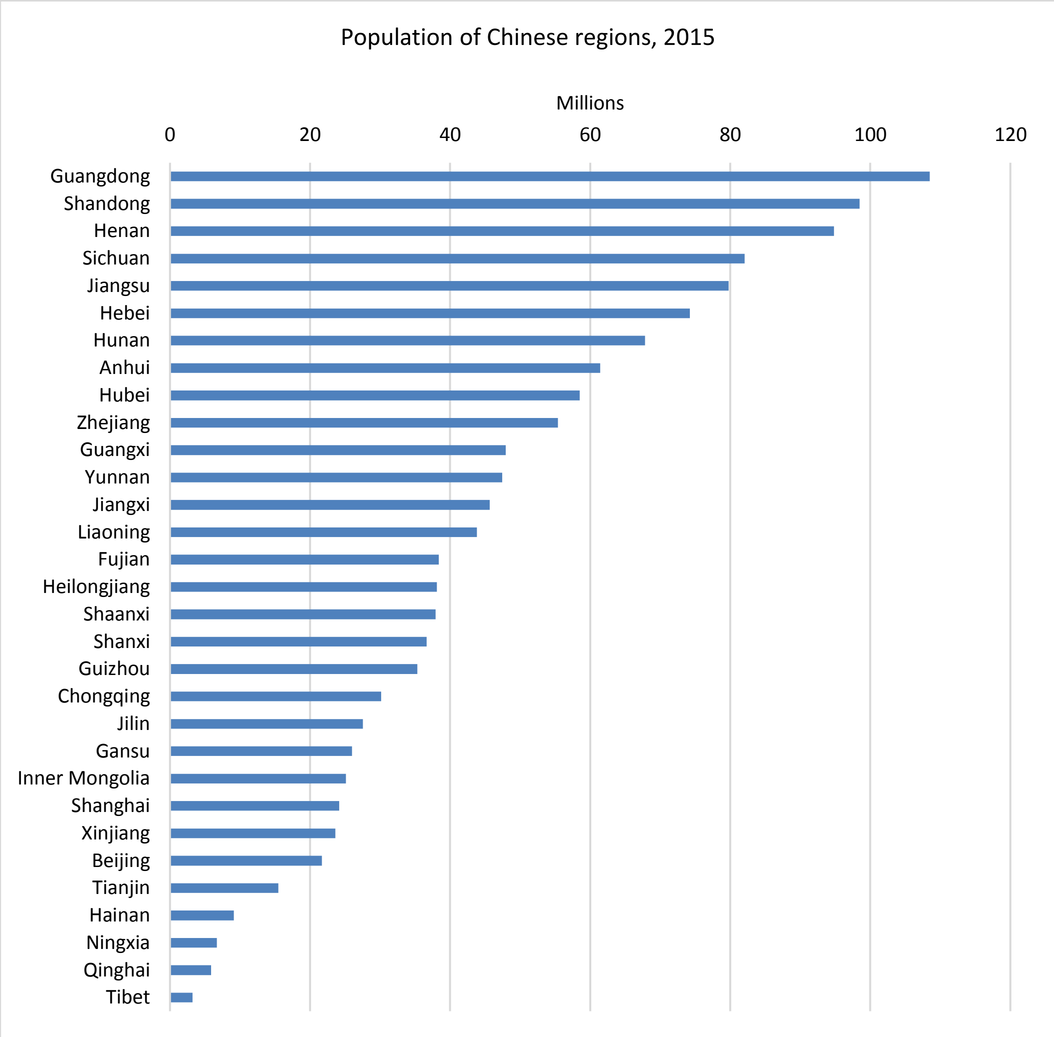

Figure 2. Number of population in the Chinese provinces and other administrative regions. Source: Statista (2017).

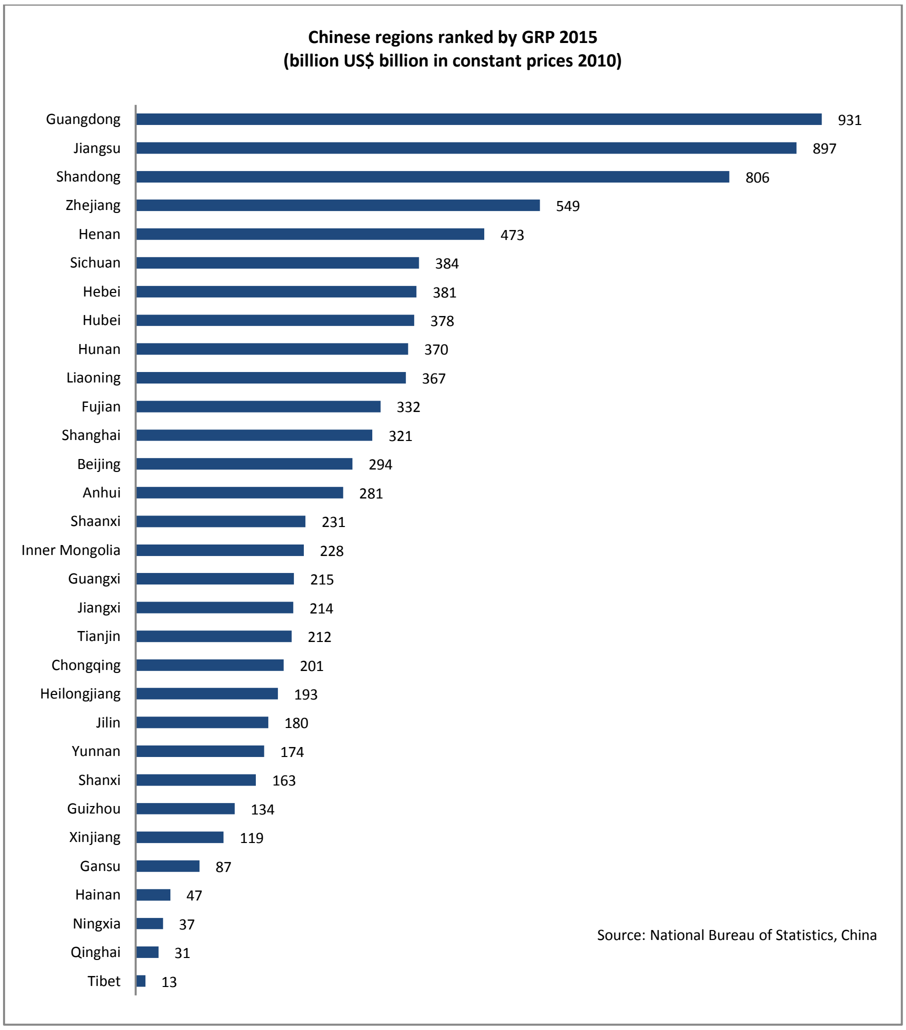

Figure 3. Chinese administrative regions ranked by GRP in real prices 2015. Source: NBS (2017).

The resources and databases used in the analyses presented in this deliverable include the following:

- China's Statistical Yearbook, National Bureau of Statistics (中国统计年鉴): http://www.stats.gov.cn/english/statisticaldata/AnnualData/
- National Bureau of Statistics (Easy Query): http://data.stats.gov.cn/english/easyquery.htm?cn=E0103
- Energy Statistical Yearbook (中国能源统计年鉴): http://tongji.oversea.cnki.net.resources.asiaportal.info/oversea/engnavi/HomePage.aspx?id=N2015110114&name=YCXME&floor=1
- Regional statistical agencies:
  - Beijing Statistical Yearbook (北京统计年鉴): http://www.bjstats.gov.cn/nj/main/2015/tjnj/zk/indexeh.htm (English Version)
  - Guangdong Statistical Yearbook (能源统计年鉴) http://tongji.cnki.net/overseas/engnavi/HomePage.aspx?id=N2011090056&name=YGDTJ&floor=1

- Hebei Statistical Yearbook (**河北**统计年鉴):
  http://www.hetj.gov.cn/hetj/tjsj/jjnj/ (contains English version)
- Shandong Statistical Yearbook (**能源**统计年鉴)
  http://www.stats-sd.gov.cn/gtb/index.jsp?url=http%3A%2F%2Fwww.stats-sd.gov.cn%2Ftjnj%2Fnj2015%2Findexeh.htm
- Tianjin Statistical Yearbook (**天津**统计年鉴):
  http://www.stats-tj.gov.cn/Category_29/Index.aspx

Decomposition analysis of total primary energy supply and CO_2 emissions in China at the regional level

ASA decomposition methodology

Decomposition analysis of total primary energy supply (TPES) in the Chinese provinces and other administrative regions is based on the following master equation (1):

$$TPES = \frac{TPES}{FEC} \times \frac{FEC}{GRP} \times \frac{GRP}{EMP} \times \frac{EMP}{POP} POP \quad (1)$$

where TPES is total primary energy supply, FEC is final energy consumption, GRP is gross regional product in fixed prices, EMP is the amount of employed persons and POP is the amount of population in the region. The decomposed effects of the factors identified in the master equation of total primary energy supply (1) are calculated as follows in equations 2-5:

$$TPES / FEC = (FEC_{t-1} + \lambda_1 \Delta FEC_{tt-1}) \times \Delta\left(\frac{TPES}{FEC}\right)_{tt-1} \quad (2a)$$

$$FEC = \left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times \Delta FEC_{tt-1} \quad (2b)$$

$$FEC / GRP = \left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times (GRP_{t-1} + \lambda_2 \Delta GRP_{tt-1}) \times \Delta\left(\frac{FEC}{GRP}\right)_{tt-1} \quad (3a)$$

$$GRP = \left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times \left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right] \times \Delta GRP_{tt-1} \quad (3b)$$

$$GRP / EMP = \left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right] \times \left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right] \times \left(EMP_{t-1} + \lambda_3 \Delta EMP_{tt-1}\right) \times \Delta\left(\frac{GRP}{EMP}\right)_{tt-1} \quad (4a)$$

$$EMP = \left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right]\times \left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right]\times \left[\left(\frac{GRP}{EMP}\right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{GRP}{EMP}\right)_{tt-1}\right]\times \Delta EMP_{tt-1} \tag{4b}$$

$$EMP/POP = \left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right]\times \left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right]\times \left[\left(\frac{GRP}{EMP}\right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{GRP}{EMP}\right)_{tt-1}\right]\times \left(POP_{t-1} + \lambda_4 \Delta POP_{tt-1}\right)\times \Delta\left(\frac{EMP}{POP}\right)_{tt-1} \tag{5a}$$

$$POP = \left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right]\times \left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right]\times \left[\left(\frac{GRP}{EMP}\right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{GRP}{EMP}\right)_{tt-1}\right]\times \left[\left(\frac{EMP}{POP}\right)_{t-1} + (1-\lambda_4)\times\Delta\left(\frac{EMP}{POP}\right)_{tt-1}\right]\times \Delta POP_{tt-1} \tag{5b}$$

Decomposition of carbon dioxide emissions from fuel combustion (CO_2) is based on the following master equation (6):

$$CO2 = \frac{CO2}{TPES}\times\frac{TPES}{FEC}\times\frac{FEC}{GRP}\times\frac{GRP}{EMP}\times\frac{EMP}{POP}\times POP \tag{6}$$

The decomposed effects of the factors identified in the master equation (6) are calculated as presented in equations 7-11:

$$CO2/TPES = (TPES_{t-1} + \lambda_1 \Delta TPES_{tt-1})\times \Delta\left(\frac{CO2}{TPES}\right)_{tt-1} \tag{7a}$$

$$TPES = \left[\left(\frac{CO2}{TPES} \right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES} \right)_{tt-1} \right] \times \Delta TPES_{tt-1} \quad (7b)$$

$$TPES/FEC = \left[\left(\frac{CO2}{TPES} \right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES} \right)_{tt-1} \right] \times$$
$$(FEC_{t-1} + \lambda_2 \Delta FEC_{tt-1}) \times \Delta\left(\frac{TPES}{FEC} \right)_{tt-1} \quad (8a)$$

$$FEC = \left[\left(\frac{CO2}{TPES} \right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \Delta FEC_{tt-1} \quad (8b)$$

$$FEC/GRP = \left[\left(\frac{CO2}{TPES} \right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \quad (9a)$$
$$\left(GRP_{t-1} + \lambda_3 \Delta GRP_{tt-1} \right) \times \Delta\left(\frac{FEC}{GRP} \right)_{tt-1}$$

$$GRP = \left[\left(\frac{CO2}{TPES} \right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times \quad (9b)$$
$$\left[\left(\frac{FEC}{GRP} \right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{FEC}{GRP} \right)_{tt-1} \right] \times \Delta GRP_{tt-1}$$

$$GRP/EMP = \left[\left(\frac{CO2}{TPES} \right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{TPES}{FEC} \right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC} \right)_{tt-1} \right] \times$$
$$\left[\left(\frac{FEC}{GRP} \right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{FEC}{GRP} \right)_{tt-1} \right] \times \quad (10a)$$
$$\left(EMP_{t-1} + \lambda_4 \Delta EMP_{tt-1} \right) \times \Delta\left(\frac{GRP}{EMP} \right)_{tt-1}$$

$$EMP = \left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right]\times$$
$$\left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right]\times$$
$$\left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right]\times \tag{10b}$$
$$\left[\left(\frac{GRP}{EMP}\right)_{t-1} + (1-\lambda_4)\Delta\left(\frac{GRP}{EMP}\right)_{tt-1}\right]\times \Delta EMP_{tt-1}$$

$$EMP/POP = \left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right]\times$$
$$\left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right]\times$$
$$\left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right]\times \tag{11a}$$
$$\left[\left(\frac{GRP}{EMP}\right)_{t-1} + (1-\lambda_4)\Delta\left(\frac{GRP}{EMP}\right)_{tt-1}\right]\times$$
$$(POP_{t-1} + \lambda_5 \Delta POP_{tt-1})\times\Delta\left(\frac{EMP}{POP}\right)_{tt-1}$$

$$POP = \left[\left(\frac{CO2}{TPES}\right)_{t-1} + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES}\right)_{tt-1}\right]\times$$
$$\left[\left(\frac{TPES}{FEC}\right)_{t-1} + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC}\right)_{tt-1}\right]\times$$
$$\left[\left(\frac{FEC}{GRP}\right)_{t-1} + (1-\lambda_3)\Delta\left(\frac{FEC}{GRP}\right)_{tt-1}\right]\times \tag{11b}$$
$$\left[\left(\frac{GRP}{EMP}\right)_{t-1} + (1-\lambda_4)\Delta\left(\frac{GRP}{EMP}\right)_{tt-1}\right]\times$$
$$\left[\left(\frac{EMP}{POP}\right)_{t-1} + (1-\lambda_5)\Delta\left(\frac{EMP}{POP}\right)_{tt-1}\right]\times \Delta POP_{tt-1}$$

In all equations 2-5 and 7-11 above, subscript *tt-1* refers to a change between a calendar year *t* and the previous year *t-1*. Subscript t refers to absolute value of an indicator in a calendar year, and *t-1* refers to the absolute value of the previous year. Coefficients $\lambda_1 \ldots \lambda_4$ define how the joint effect of the two variables are divided into the corresponding factor in each two-factor decomposition chain. In equations 2-5 and 7-11, the calculated effects are separated by a and b in the equations. In all decomposition analyses carried out in the EUFORIE project, the coefficients determining the division are $\lambda_1=\lambda_2=\lambda_3=\lambda_4=\lambda_5=0.5$.

Master equation (1) for total primary energy supply and master equation (6) for carbon dioxide emissions from fuel combustion (CO_2) include the following drivers:

- Driver CO_2/TPES (carbon dioxide emissions divided by total primary energy supply) represents carbon intensity of the primary energy mix. The intensity may change due to fuel switch, i.e. change from one primary energy source to another such as from fossil fuels to renewables or from coal to gas etc.
- Driver TPES/FEC (total primary energy supply divided by final energy consumption) represents the efficiency of the energy transformation system in the analysed province or region. This efficiency changes when changes in the transformation process take place, e.g. when fuel use is replaced with electricity. If electricity is produced in condensing power plants, the transformation process becomes more inefficient because in condensing power plants only 35-40 % of the fuel's energy content is transformed into electricity, the rest is waste heat. Thus, a drop in the efficiency of the energy transformation process increases the need of primary energy (TPES).
- Driver FEC/GRP (final energy consumption divided by gross regional product) describes energy intensity of the regional economy, which is an inverse of energy efficiency. Changes in this driver are due to changes in the structure of the regional economy, such as change from energy intensive to lighter industrial branches and services or vice versa.
- Driver GRP/EMP (gross regional product divided by number of employed people), GRP per worker, describes the labour productivity.
- Driver EMP/POP describes the share of employed people among the entire population.
- Driver POP (number of population) is an important driver, increasing population consumes more energy.

Special reference in the EUFORIE project is made to the drivers TPES/FEC and FEC/GDP, because they are indicators directly describing energy efficiency at the national level. They are relevant also at other levels as indicated in work packages WP6 and WP8 of the EUFORIE project.

Ideally, total primary energy supply (TPES) consists of (i) final energy consumption (FEC), (ii) all losses when primary energy is transformed into energy carriers, and (iii) losses in the transfer and distribution of energy carriers (such as electricity) into the sites of final consumption. However, in some cases such as electricity generation from hydro, wind, solar, geothermal, and nuclear energy, measuring the amount of primary energy is difficult or impossible. In these cases different practices have been developed. In International Energy Agency statistics, which are used in the empirical analyses of this report, hydro, wind and solar power are included as electricity in the primary energy, so statistically their transformation is 100 % efficient. In the case of nuclear, on the other hand, it has been assumed that electricity is generated with a 33 % thermal efficiency. In other words, one unit of nuclear electricity requires three units of primary energy. In the case of geothermal electricity, a 10 % thermal efficiency is assumed – one nit of geothermal electricity requires ten units of primary energy.

Thus, a comparison between different countries is challenging – e.g. the difference between Norway (with lot of hydro) and France (lot of nuclear) may look too large in terms of primary energy.

Data description

For provincial level analysis, two databases were compiled based on the information provided by China's statistical yearbooks published between 2006 and 2016. In addition, various parameters were collected from the China's National Bureau of Statistics (NBS) on-line database (see NBS 2017).

The provincial level database contains information about 20 regions of China including provinces, municipalities, and autonomous regions. The information covers both economic and energy characteristics of each region. Several statistical units such as GDP in constant prices and CO_2 emissions were computed separately, based on parameters provided by international databases.

In NBS Gross-Domestic Product (GDP) is computed based on a combination of production and income methods rather than focused on the expenditure approach as in the World Bank, International Monetary Fund (IMF), and American databases. Gross Regional Product (GRP) is the parameter equivalent to GDP, but for regions or administrative units as in the case of China. It seems that provincial data can be considered as more accurate since the complete income data collected only on the provincial level while central NBS relies not on the full provincial information, but on the direct reports from industries (Holz 2014). GDP and GRP are released at nominal RMB prices. Therefore, they were transferred to 2010 real prices and $US through the deflator provided by The International Monetary Fund and the US dollar-RMB exchange rate from The World Bank database respectively.

Total primary energy supply (TPES; Figure 4) and final energy consumption (FEC) were collected from provincial statistical yearbooks 2006-2015, energy balance sheets. Initially, these energy figures are represented in tonnes of coal equivalent (tce), but for the further comparative analysis, they were transferred to tonnes of oil equivalent (toe).

Neither Chinese National Bureau of Statistics (NBS) nor the provincial statistical yearbooks provide information on carbon dioxide emissions. It was computed through IPCC emission factors from total primary energy supply for each province and other administrative region independently (Figure 5).

Annex 1 of this deliverable incudes a description of data collection in Chinese statistics with special reference to regional statistics.

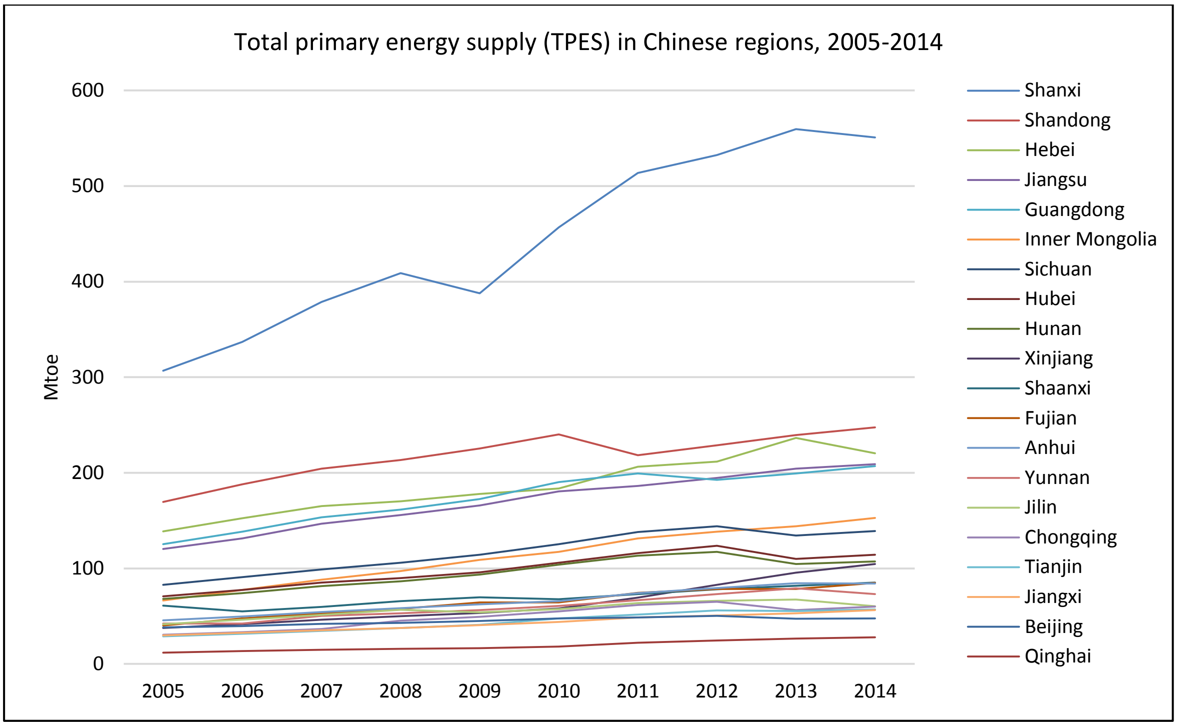

Figure 4. Total primary energy supply (TPES) in the 20 Chinese provinces and other administrative regions, 2005-2014.

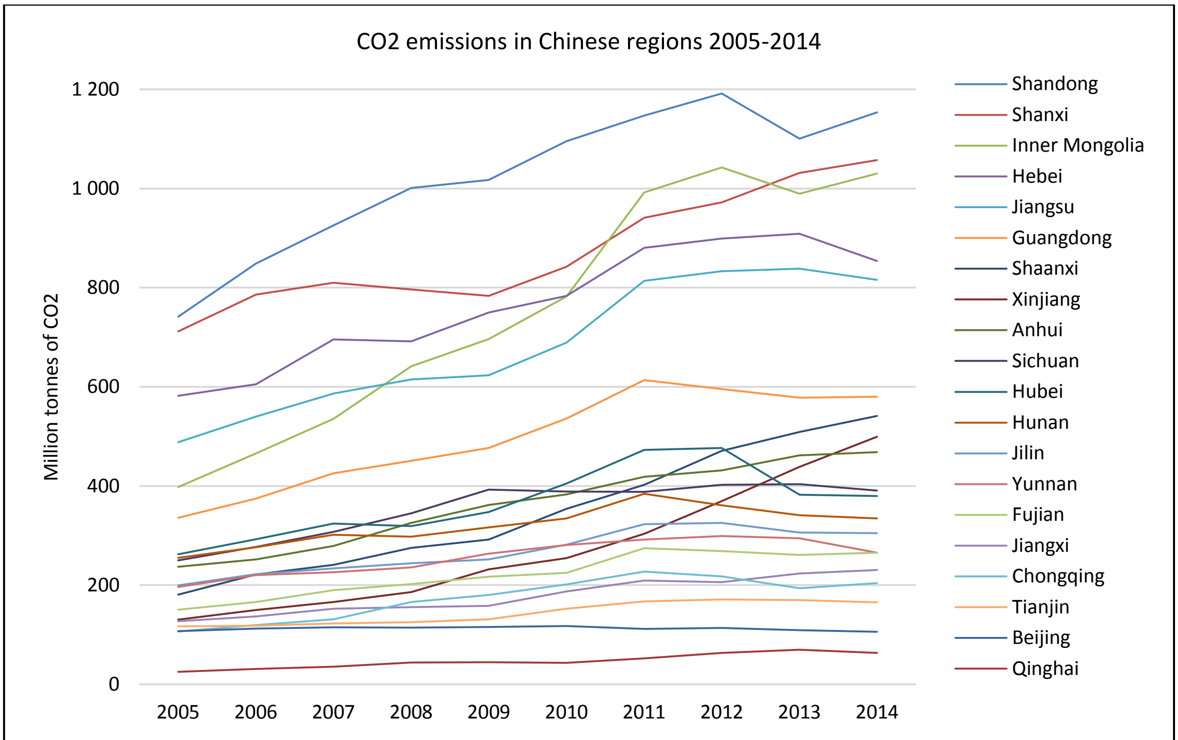

Figure 5. Carbon dioxide emissions from fuel combustion (CO_2) in the 20 Chinese provinces and other administrative regions, 2005-2014.

Results of decomposition analyses

In the following, a decomposition analysis of total primary energy supply (TPES) and CO_2 emissions from fuel combustion will be carried out for the 20 Chinese provinces and other administrative regions. The results are presented for the change between the years 2005 and 2014, but the reader has an opportunity to look also other time periods between these years by summing up the annual changes provided by the incremental decomposition analysis applied in this deliverable. The annual results are included in Annex 2 for total primary energy supply (TPES) and in Annex 3 for carbon dioxide emissions from fuel combustion (CO_2).

The drivers of TPES and CO_2 emissions are identified above in master equations (1) and (6) applying the methodology for calculating the effects of the drivers described in equations (2)-(5) and (7)-(11), correspondingly. Figures 6-25 show the decomposition results for both TPES and CO_2 in each of the 20 analysed Chinese regions between the years 2005 and 2014. In each figure, the column in the right shows the change of TPES and CO_2, and the other columns show the decomposed contribution of each driver to the change. The sum of the drivers equals to the observed change in TPES and CO_2.

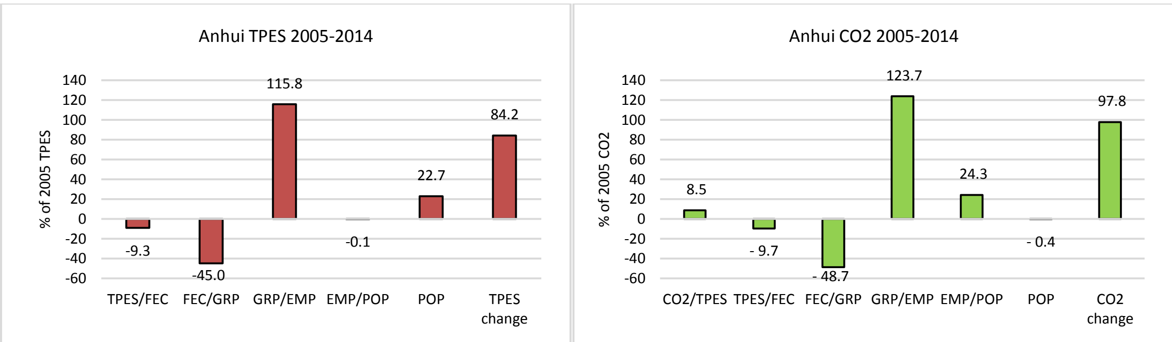

Figure 6. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Anhui province, 2005-2014.

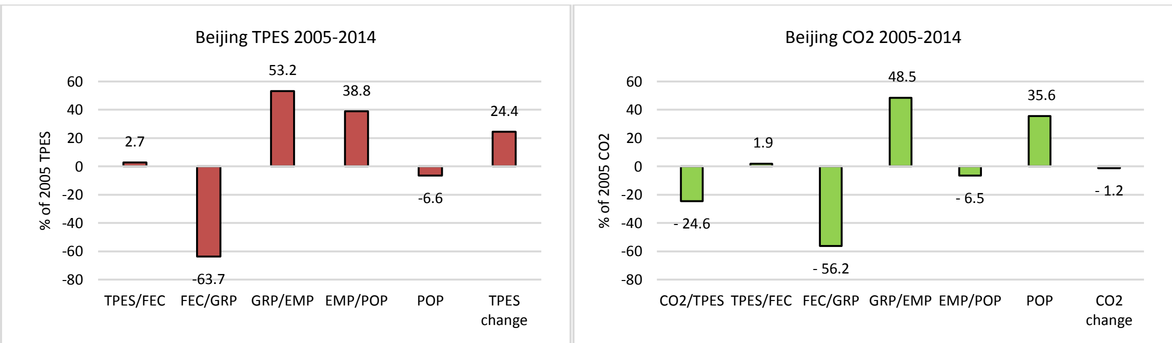

Figure 7. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Beijing municipality, 2005-2014.

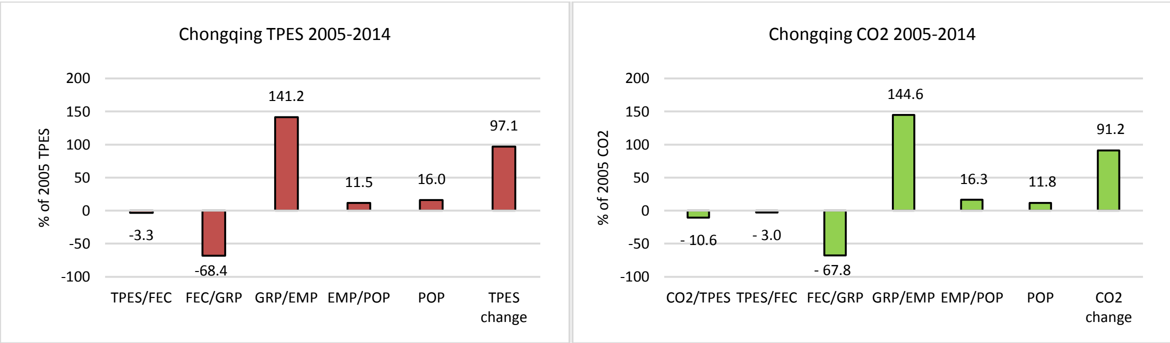

Figure 8. Decomposition of total primary energy supply (TPES) and CO_2 emissions in Chongqing municipality, 2005-2014.

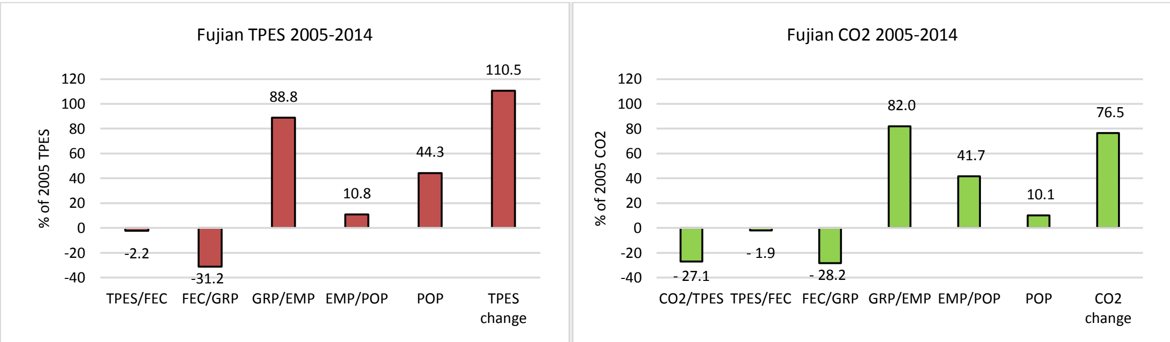

Figure 9. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Fujian province, 2005-2014.

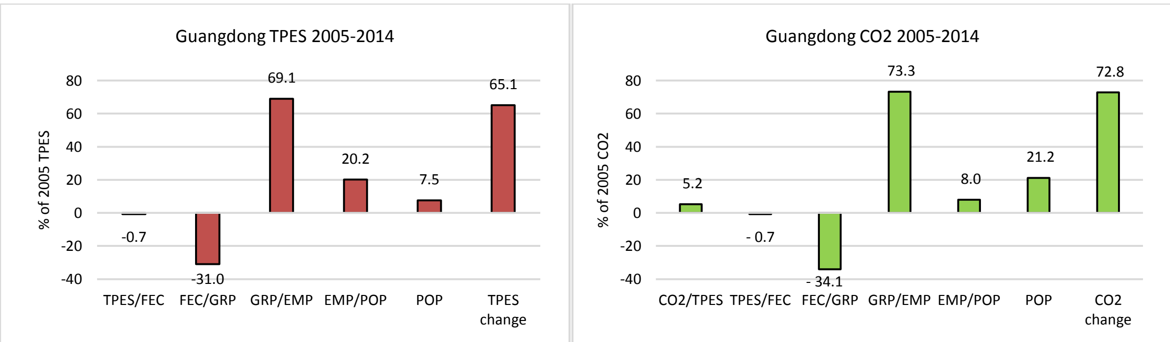

Figure 10. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Guangdong province, 2005-2014.

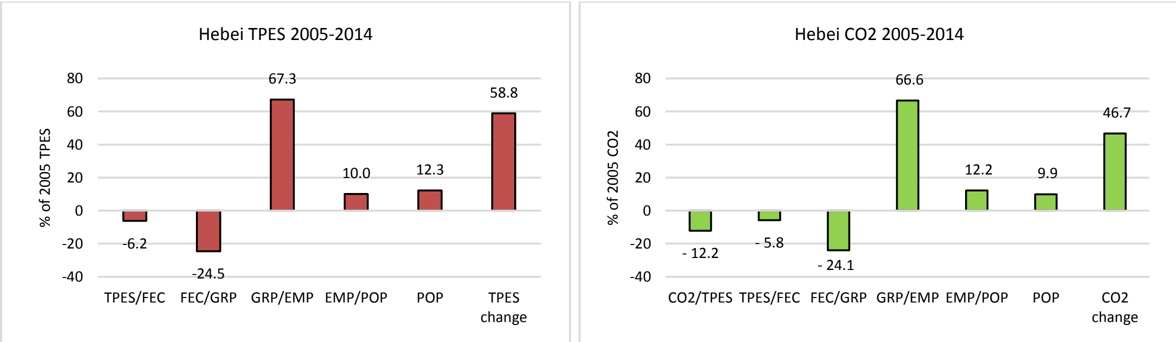

Figure 11. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Hebei procince, 2005-2014.

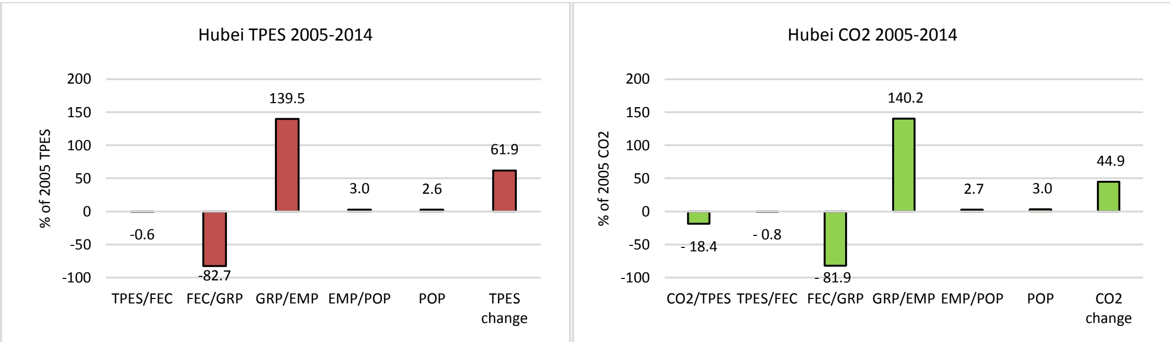

Figure 12. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Hubei province, 2005-2014.

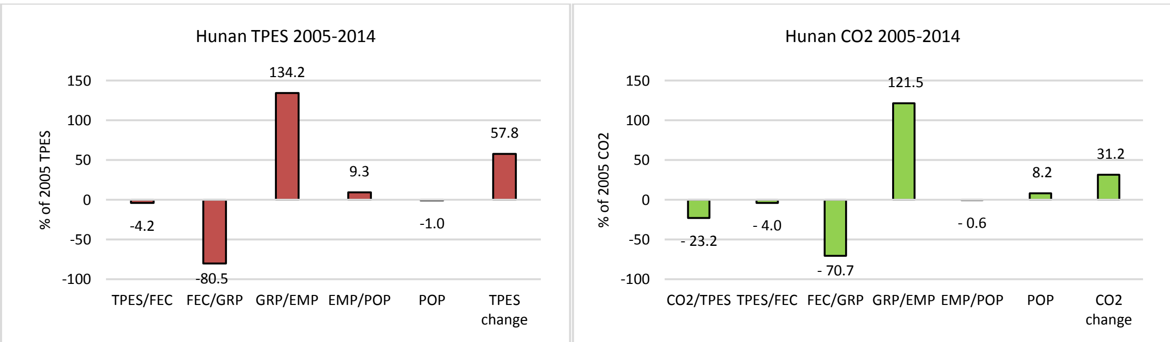

Figure 13. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Hunan procince, 2005-2014.

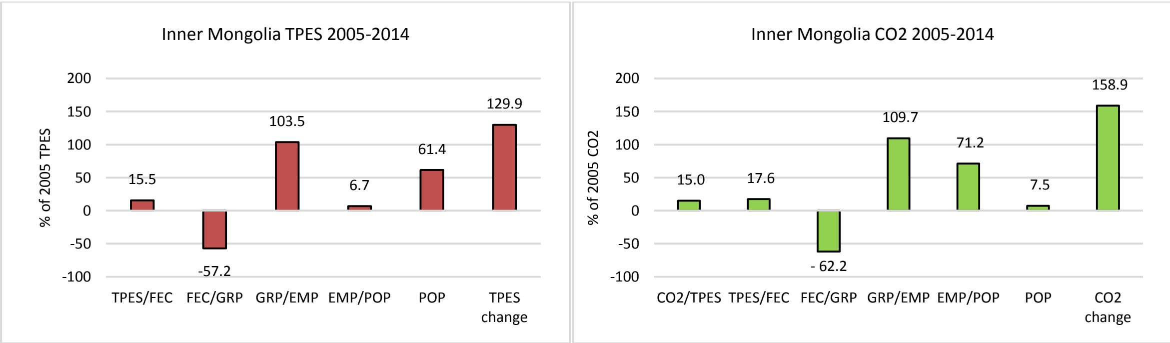

Figure 14. Decomposition of total primary energy supply (TPES) CO_2 emissions in the Inner Mongolia autonomous region, 2005-2014.

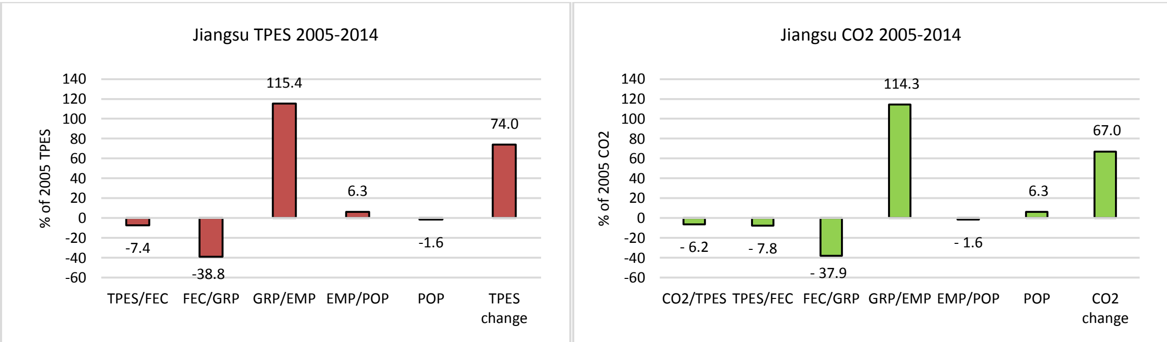

Figure 15. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Jiangsu province, 2005-2014.

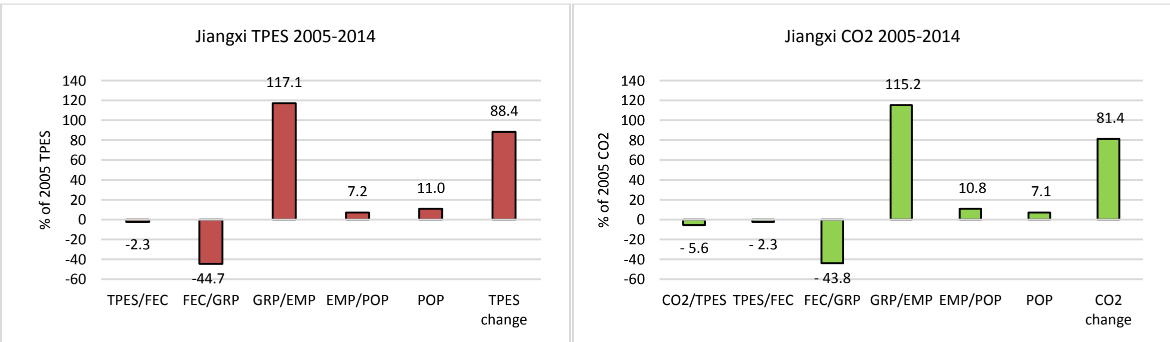

Figure 16. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Jiangxi province, 2005-2014.

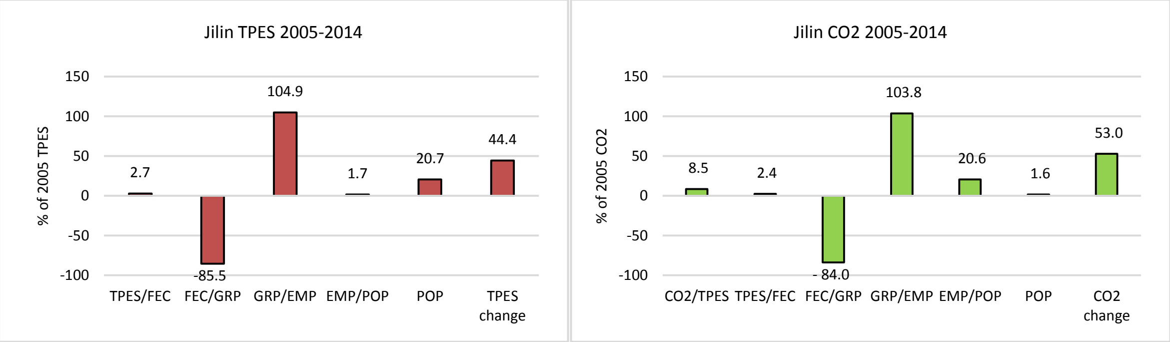

Figure 17. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Jilin province, 2005-2014.

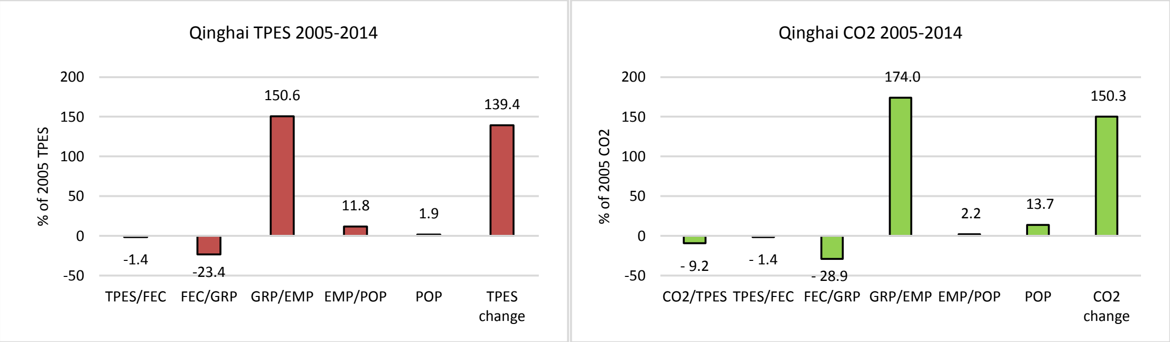

Figure 18. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Qinghai Shaanxi provinve, 2005-2014.

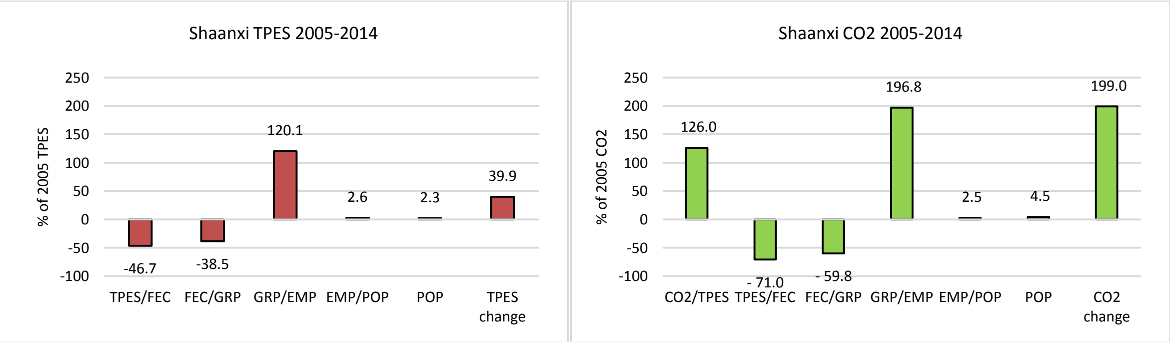

Figure 19. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Shaanxi province, 2005-2014.

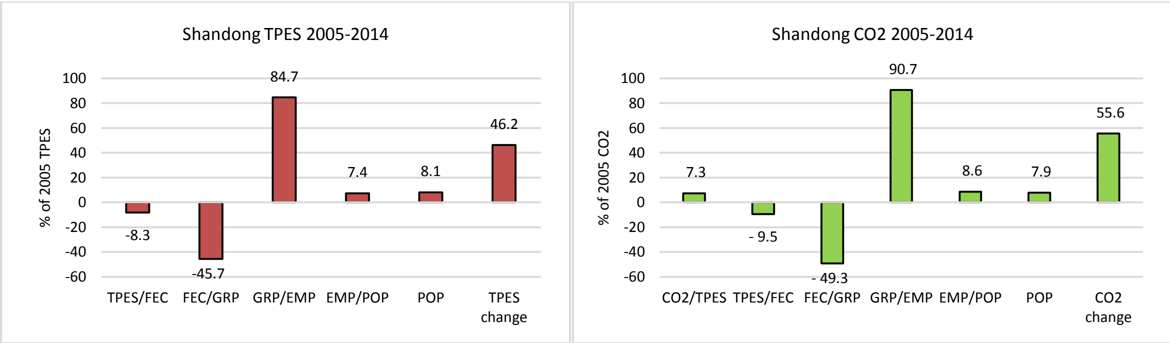

Figure 20. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Shandong province, 2005-2014.

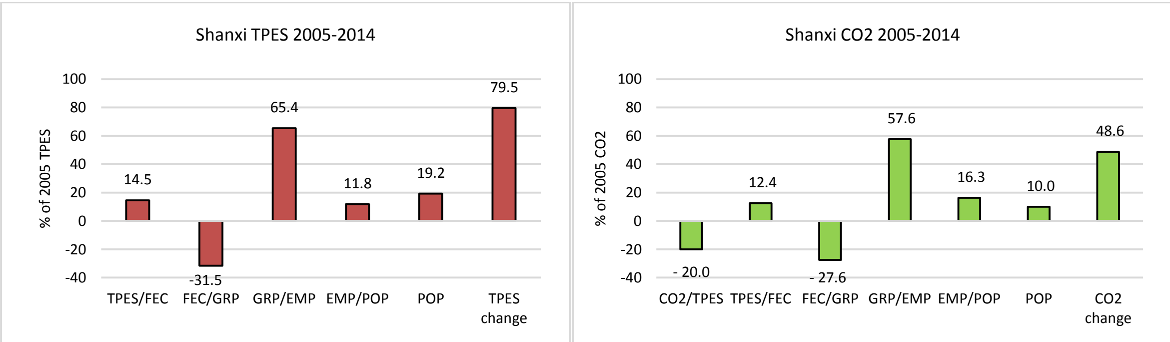

Figure 21. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Shanxi province, 2005-2014.

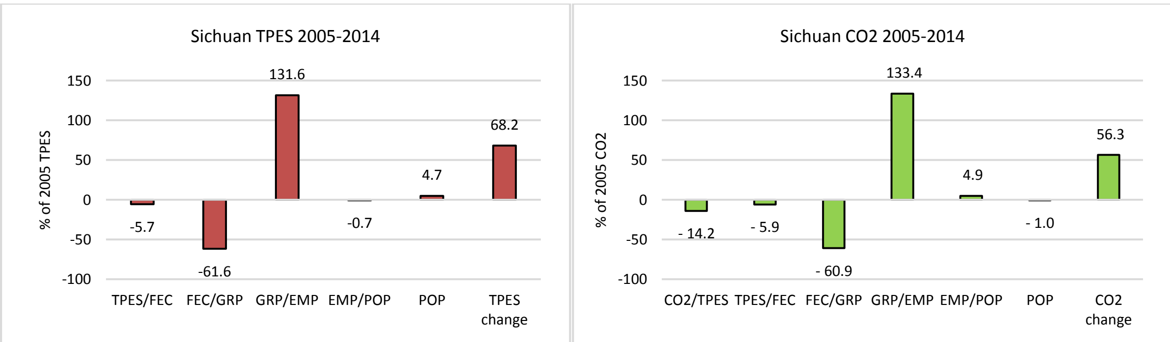

Figure 22. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Sichuan province, 2005-2014.

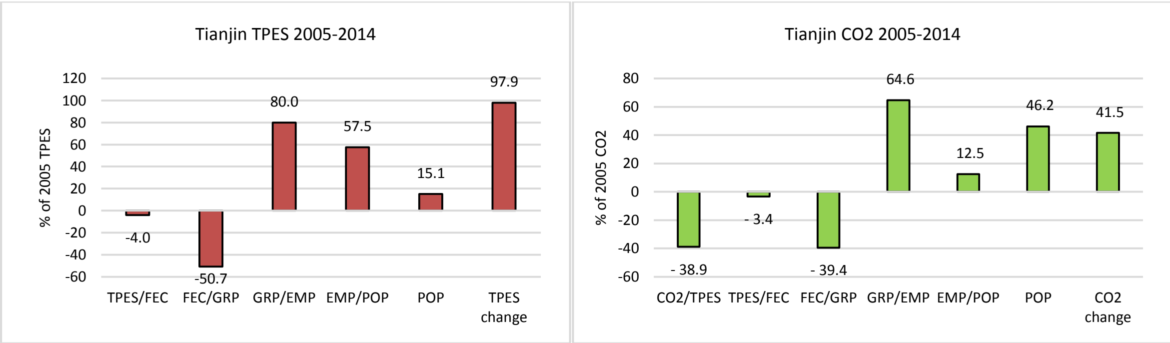

Figure 23. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Tianjin municipality, 2005-2014.

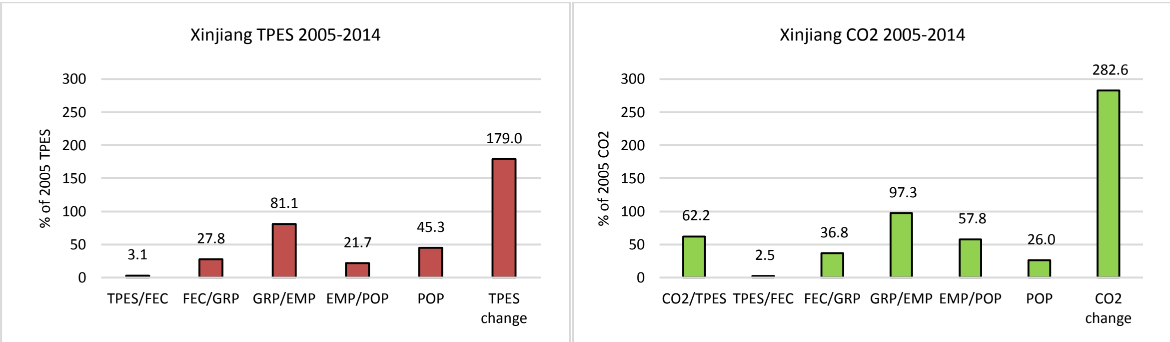

Figure 24. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Xinjiang autonomous region, 2005-2014.

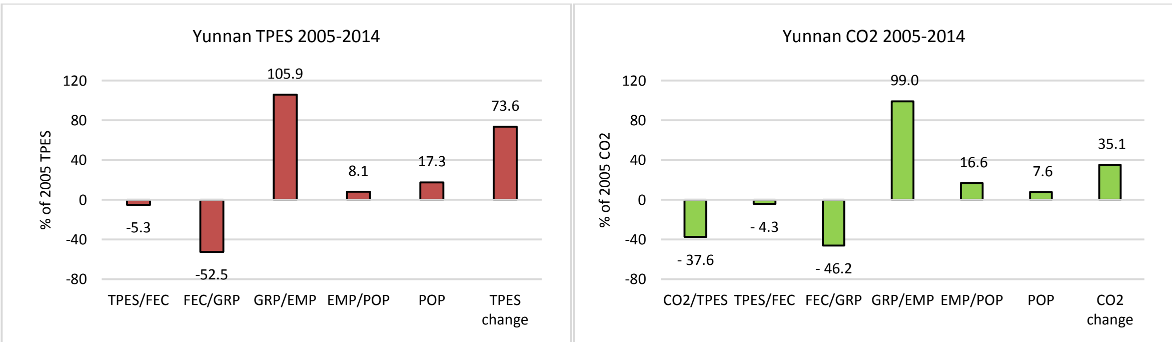

Figure 25. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Yunnan province, 2005-2014.

Total primary energy supply (TPES) has increased between the years 2005-2014 in all Chinese regions analysed in this deliveable. The increase varies between 24 % in the Beijing municipality (Figure 7) and 179 % in the Xinjiang autonomous region (Figure 24). Also in the Qinghai province (139 %), in the autonomous region of Inner Mongolia (130 %), and in the Fujian province (111 %), total primary energy supply (TPES) has more than doubled in a 10 years period (Figures 18, 14 and .9, respectively).

Inside this 10 years period, annual variation is quite low in most of the regions. Annual growth in total primary energy supply (TPES) has been quite stabile in most of the studies regions (Annex 2). Notable (more than 10 %) annual decreases in TPES have occurred in a few regions such as in Chongqing 2012-2013, in Hubei 2012-2013, in Hunan 2012-2013, and in Jilin 2013-2014 (Annex 2).

The most important driver with an increasing effect has been “labour productivity” (GRP/EMP), which has increased primary energy use (TPES) in all regions without exceptions. The drivers “employment” (EMP/POP) and “population” (POP) have slightly increased primary energy use (TPES) in most of the regions in China. In the Fujian province (Figure 9) and in the autonomous region of Inner Mongolia (Figure 14), change in the amount of population (POP) has increased primary energy use (TPES) the most. A significant increasing contribution to primary energy use (TPES) has come from the driver EMP/POP in the two very urban regions, the municipality of Beijing (Figure 7) and the municipality of Tianjin (Figure 23). The most urban Chinese region, the municipality of Shanghai, was not among the analysed regions due to problems in data availability.

The most significant decreasing effect to primary energy use (TPES) has come from the driver “energy intensity” (FEC/GRP), which reflects a change in the regional economic structure, and may reflect changing energy efficiency of the production processes in the regional economy too. To analyse this decreasing effect in more detail, four regions are selected as examples (see the next chapter). In one region only, in the Xinjiang autonomous region (Figure 24), change in energy intensity has increased primary energy use (TPES).

The driver TPES/FEC represents change in the efficiency of the entire energy transformation system and can be explained by e.g. changes in the energy mix, has not had any significant effect in primary energy use (TPES) in most of the regions. Decreasing effect of this driver is, however, worth mentioning in the Shaanxi province (Figure 19).

Carbon dioxide emissions from fuel combustion (CO_2) have also increased during the years 2005-2014 in all Chinese regions, except the Xinjiang autonomous region (Figure 24). In Xinjiang, emissions have slightly decreased (-1.2 %) in a ten years period. The increase varies from 31 % in the Jilin province (Figure 17) to 283 % in the Hunan province (Figure 13). In Hunan, CO_2 emissions have almost tripled during a ten years period. CO_2 emissions have more than doubled also in the Shaanxi province (199 %; Figure 19), in the autonomous region of Inner Mongolia (159 %; Figure 14), and in the Qinghai province (150 %; Figure 18).

Inside this 10 years period, it seems that the annual increases have slowed down and annual decreases are quite common in many regions after the year 2010. Regions with at least two annual decreases after 2010 include Beijing, Chongqing, Fujian, Guangdong, Hubei, Hunan, Jilin, Tianjin and Yunnan (Annex 3). More than 10 % annual decreases have taken place in Chongqing 2012-2013 and in Hubei 2012-2013 (Annex 3).

Like in the case of total primary energy supply (TPES), also in the case of CO_2 emissions from fuel combustion the most important driver with an increasing effect has been “labour productivity” (GRP/EMP). This driver is the most important increaser of emissions in all Chinese regions except the Hunan province (Figure 13). In Hunan, carbon intensity of primary energy (CO_2/TPES) has had even a more significant increasing effect. This indicates a huge increase in the use of coal and other carbon intensive fossil fuels in Hunan.

The driver “carbon intensity” (CO_2/TPES) has had both increasing and decreasing effects in different Chinese regions. In addition to the Hunan province, this driver has had significant increasing effects in the provinces of Chongqing (Figure 8), Hebei (Figure 12), Shangding (Figure 20) and Yunnan (Figure 25), and in the municipality of Beijing (Figure 7). In these regions, the growth of CO_2 emissions has been faster than the growth of TPES, which indicates that the share of carbon intensive energy sources (such as coal and coke) has increased in the energy mix. Significant decreasing effects have been in e.g. the provinces of Fujian (Figure 9), Jiangxi (Figure 16) and Qinghai (Figure 18), in the Xinjiang autonomous region (Figure 24), and in the municipality of Tianjin (Figure 23). In these regions, the growth of TPES has been faster than the growth of CO_2 emissions, which indicates a switch from coal and coke to less carbon intensive primary energy sources during the studied period.

Further analysis of four selected Chinese regions

For a further analysis, four administrative regions were chosen: the provinces of Guangdong, Hebei and Shandong, and the municipality of Tianjin. The selection was influenced by (1) the combination of the regional economy (GRP; Figure 3), (2) proportions of urban and rural population (Figure 26), (3) CO_2 emissions (Figure 5), and (4) access to the regional statistics. The idea was to select a few regions for the further analysis which are interesting and different from each other.

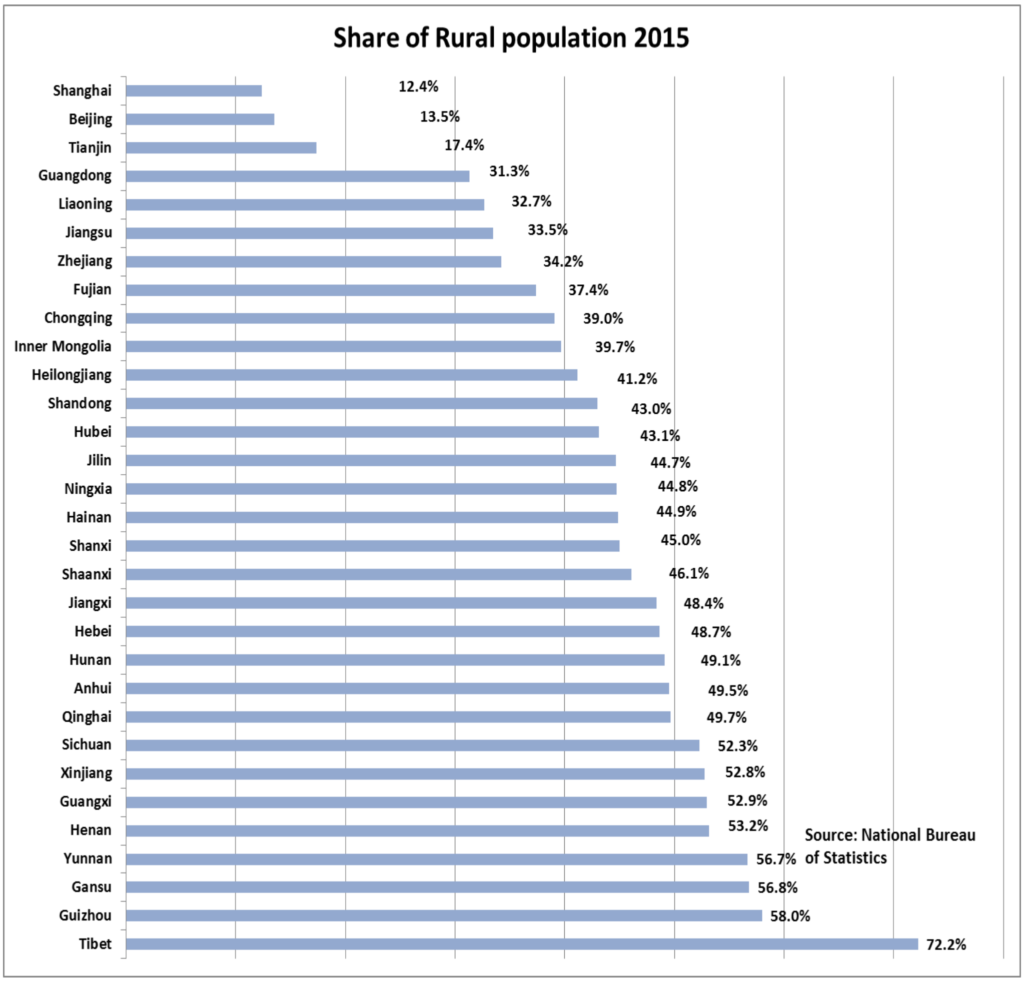

Figure 26. Share of rural population in the Chinese administrative regions, 2015.

The Guangdong province

Guangdong is an urban province with a relatively low proportion of rural population (Figure 26). In 2014, it had the highest GRP in China (Figure 3), but relatively low absolute CO_2 emissions for a manufacturing province, 580 Mtoe (Figure 5). The province has a lot of light industry, including electrical appliances and communication equipment (Table 1). The share of industry has decreased from 72 % to 67 % during the studied period (Figure 27), and there is a slight increase in the shares of agriculture (including also forestry, animal husbandry and fishing) and the commercial sector (including wholesale and retail trade, and services such as hotels, catering etc.).

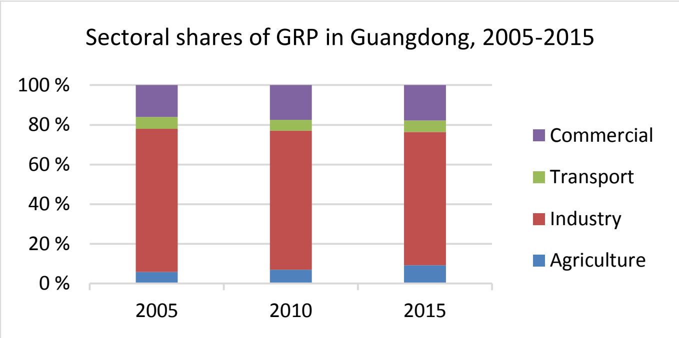

Figure 27. Sectoral shares of GRP in the Guangdong province, 2005-2015.

Table 1. Guangdong: Value-added of industry above designated size by sector.

Industrial sector	Value-added 2014 (%) of Total
Manufacture of Communication Equipment,	22
Manufacture of Electrical Machinery and Equipment	9
Production and Supply of Electric Power and Heat Power	7
Manufacture of Raw Chemical Materials and Chemical, Manufacture of Automobile, Metal Products	5 (for each industry separately)
Non-metal Mineral Products, Rubber and Plastic Products	4 (for each industry separately)

Source: Guangdong Statistical Yearbook, 2016

Figure 28 describes how different energy carriers have been used in the main economic sectors in the Guangdong province in the years 2005, 2010 and 2015. Final energy consumption (FEC) has increased in all sectors except in industry between the years 2010 and 2015. According to the regional Guangdong statistics, petroleum products dominate final energy consumption in all other sectors than industry where coal has the major share. In the Guangdong province as a whole, the share of petroleum products in final energy consumption is extremely high although it has dropped from 63 % to 52 % during the studied period. Transport is the second largest economic sector in Guangdong, which also explains the use of petroleum products. Because petroleum products together with coal and coke dominate final energy consumption in Guangdong, the shares of all other energy carriers, even electricity, remains marginal when the consumption inside the province is looked at. However, electricity production has an important role in the Guangdong economy (Table 1), and electricity is transmitted to other Chinese regions from Guangdong, which is located in the coast of the Southern China Sea (Figure 1).

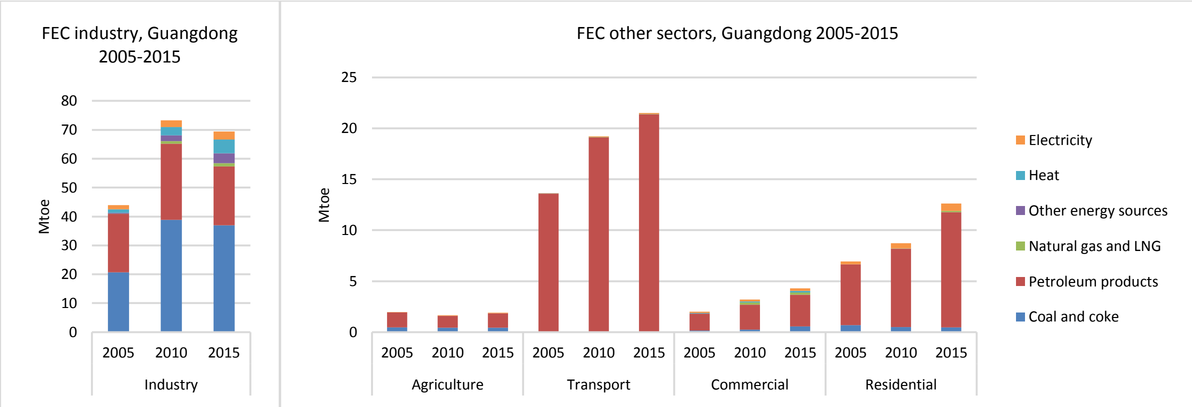

Figure 28. Final energy consumption (FEC) by sector and energy carrier in the Guangdong province, 2005-2015.

Regarding the results of the decomposition analyses, the dominance of fossil fuels in final energy consumption (FEC) explains the slightly increasing effect of driver CO_2/TPES to CO_2 emissions (Figure 29). The economic growth (the drivers "labour productivity" and "employment"; GRP/EMP and EMP/POP, respectively) have increased both total primary energy supply (TPES) and CO_2 emissions significantly. Because economic activity in Guangdong has increased faster than final energy consumption, the effect of driver FEC/GRP has been a decreasing one to TPES and CO_2. However, total primary energy supply (TPES) and CO_2 emissions from fuel combustion have increased significantly (Figure 29).

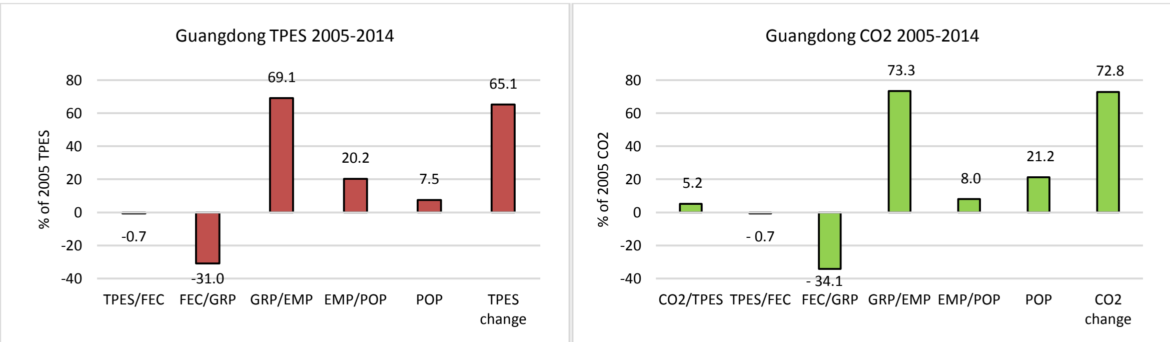

Figure 29. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Guangdong province, 2005-2014.

The Hebei province

The Hebei province has almost 50 % of the rural population (Figure 26). In 2014, GRP of Hebei was ranked as the 6th highest in China (Figure 3). The development of value added in different economic sectors is shown in Figure 30 for the years 2005, 2010 and 2015. The share of agriculture (including also forestry, animal husbandry and fishing) has been increasing in Hebei during the studied period being 19 % in the year 2015. At the same time, the share of industry has slightly decreased. The province mainly manufactures ferrous metals, chemical products, coal, petroleum, and textile (Table 2).

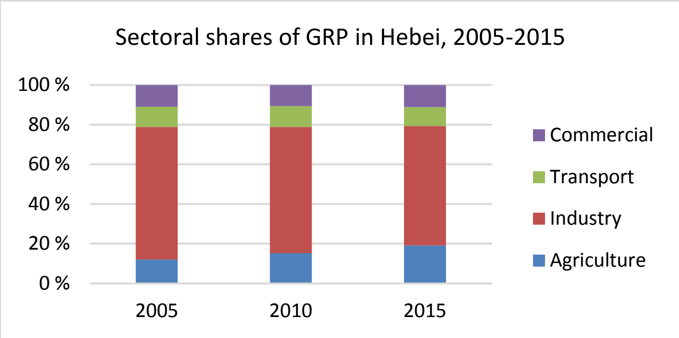

Figure 30. Sectoral shares of GRP in the Hebei province, 2005-2015.

Table 2. Hebei: Gross industrial output value of industry above designated size by sector.

Industrial sector	Gross Industrial Output Value 2014 (%) of Total
Manufacture and Processing of Ferrous Metals	24
Production and Supply of Electric Power and Heat, Manufacture of Metal Products	6 (for each industry separately)
Mining of Ferrous Metal Ores, Manufacture of Chemical Raw Material and Chemical Products, Processing of Food from Agricultural Products	5 (for each industry separately)
Manufacture of Non-metallic Mineral Products, Manufacture of Automotive, Manufacture of Electrical Machinery and Equipment	4 (for each industry separately)

Source: Hebei statistical yearbook, 2016

Figure 31 shows the structure of final energy consumption by economic sectors in the years 2005, 2020 and 2015, and inside each economic sector by energy carrier. This figure together with Figure 30 is useful, when interpreting the results of the decomposition analysis above (Figure 32 repeats the results from the Hebei province). Figure 30 shows that the share of coal has decreased especially in the residential sector, where it has been replaced by electricity and heat – as well as by petroleum products. A slight decrease in the share of coal has taken place also in the industrial sector. This explains the decreasing effect of the driver CO_2/TPES in the CO_2 decomposition (Figure 32). Despite the relatively fast increase in final energy consumption (FEC; Figure 30), the driver FEC/GRP has had a decreasing effect to total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2). Due to the even faster increase in economic growth, both total primary energy supply and CO_2 emissions have increased significantly during the studied period (Figure 32).

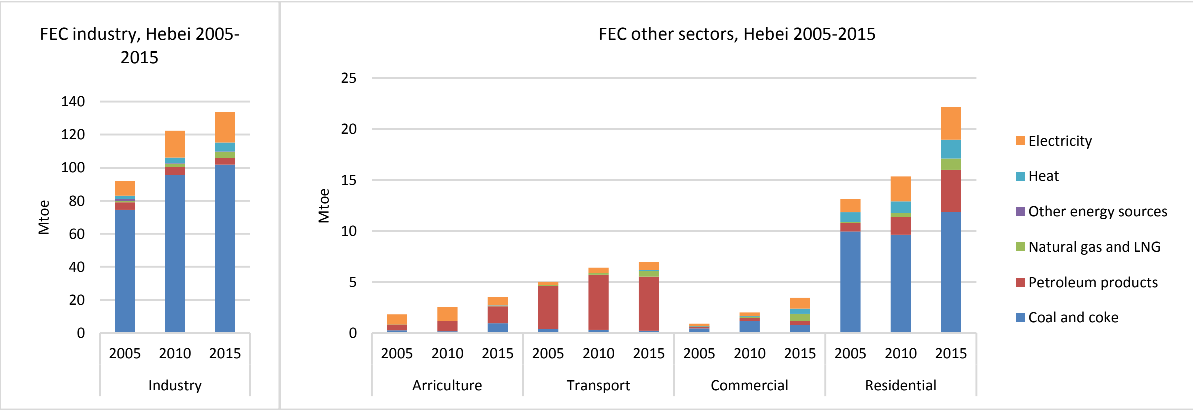

Figure 31. Final energy consumption (FEC) by sector and energy carrier in the Hebei province, 2005-2015.

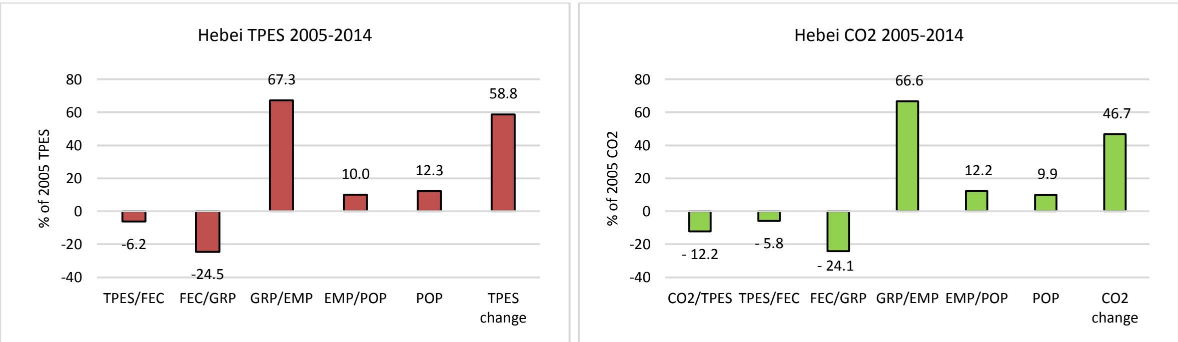

Figure 32. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Hebei procince, 2005-2014.

The Shandong province

In 2015, the Shandong province was ranked as having the third highest GRP in China (Figure 3). The province has a mixed population (43 % rural; Figure 26), the highest CO_2 emissions (Figure 5) in the country, and one of the highest shares of mining and chemical raw material manufacturing in the production structure (Table 3). These are energy-intensive industrial branches, so the industrial energy consumption is high in Shandong (Figure 34). During the studied period 2005-2015, the share of industry in the Shandong economy (GRP) has decreased from 73 % to 61 % (Figure 33). The shares of agriculture and the commercial sector have increased, but the share of transport and communication has slightly decreased.

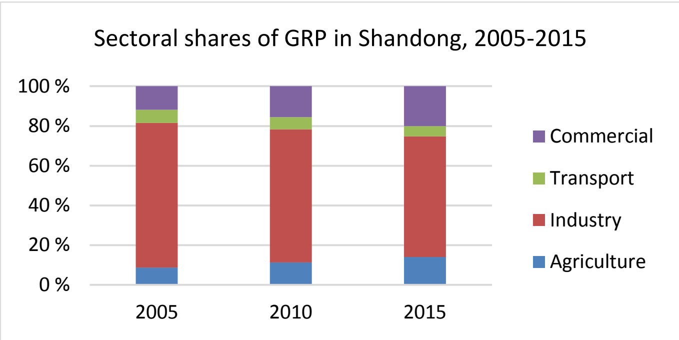

Figure 33. Sectoral shares of GRP in the Shandong province, 2005-2015.

Table 3. Shandong: Value-added of industry above designated size by sector.

Industrial sector	Value-added 2014 (%) of Total
Manufacture of Chemical Raw Material and Chemical Products	10
Processing of Food from Agricultural Products	8
Mining (Mainly Washing Coal and Extraction of Petroleum and Natural Gas)	7
Manufacture of General Purpose Machinery, Manufacture of Textile, Manufacture of Non-metallic Mineral Products	6 (for each industry separately)
Manufacture of Special Purpose Machinery, Production and Supply of Electric Power and Heat Power, Manufacture & Processing of Non-ferrous Metals, Processing of Petroleum, Coking and Nucleus Fuel, Production and Supply of Electric, Gas, and Water	4 (for each industry separately)

Source: Shandong statistical yearbook, 2016

Figure 34 shows that final energy consumption in agriculture (including forestry, animal husbandry and fishing) and the commercial sector (including wholesale and retail trade, and services such as hotels and catering) has decreased between the years 2005 and 2010 but increased again between the years 2010 and 2015. On the other hand, final energy consumption in transport and communication increased significantly between the years 2005 and 2010 but decreased almost back to the 2005 level between the years 2010 and 2015. Figure 34 also shows that the use of electricity and heat has been increasing in the Shandong province, especially in the industrial and residential sectors. The growth of final energy consumption (FEC) in these sectors is mainly due to increased use of electricity and heat. The use of natural gas has also increased in the residential sector.

Despite to the increase in the use of electricity, the driver TPES/FEC has had a small decreasing effect to both total primary energy supply (TPES) and CO_2 emissions from fuel combustion (Figure 35). Economic growth (driver GRP/EMP) has increased TPES and CO_2 the most, while the effects of other increasing drivers (EMP/POP and POP) have been rather small. As a sum of the effects of all drivers, TPES and CO_2 have increased in the Shandong province 46 % and 56 % between the years 2005 and 2014, respectively (Figure 35).

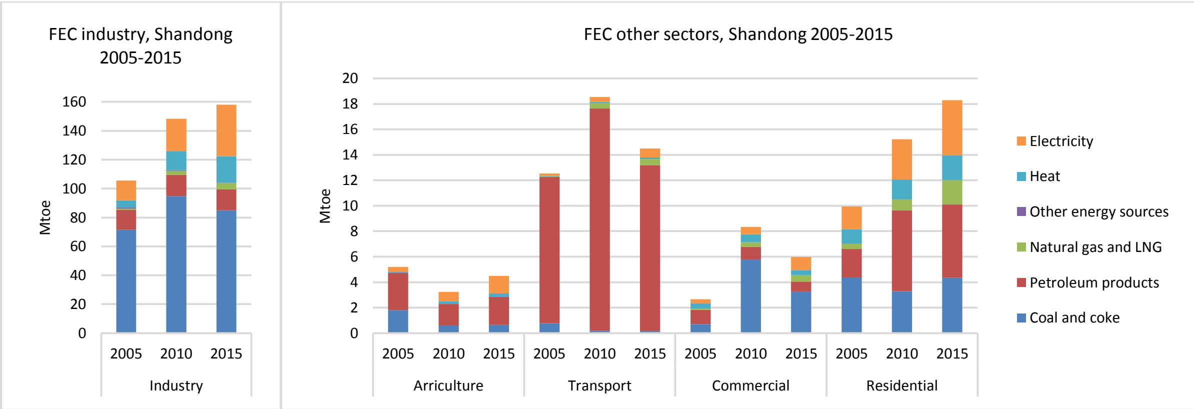

Figure 34. Final energy consumption (FEC) by sector and energy carrier in the Shandong province, 2005-2015.

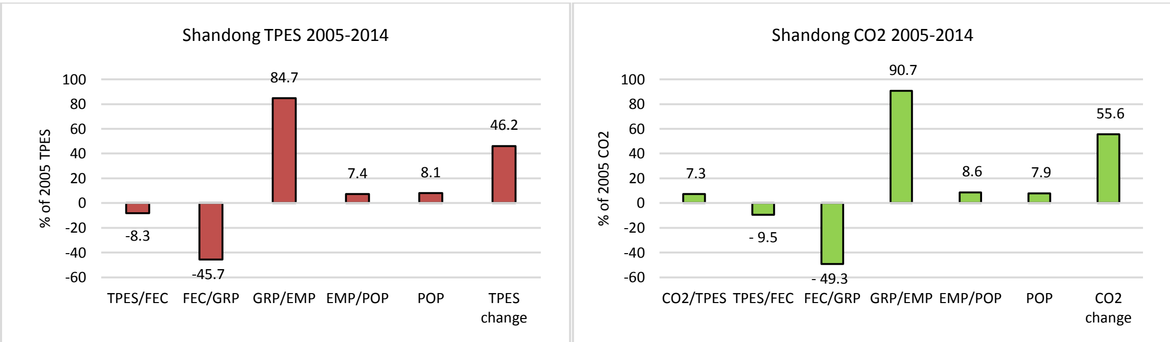

Figure 35. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Shandong province, 2005-2014.

The Tianjin municipality

Tianjin Municipality has borders with Beijing Municipality and Hebei province (Figure 1). It is ranked as the fourth largest city in China, with one of the lowest proportion of rural population around 17.4 % in 2015 (Figure 26). In comparison to Beijing Municipality, Tianjin is rarely discussed, but at the same time, Tianjin has good open sources of statistical information available. The highest gross industrial output in the area is acquired from smelting and pressing of ferrous metals, manufacturing of electronic equipment and motorcar manufacturing (Table 4). The share of agriculture is small in the economy, and the commercial/service sector has increased its share (Figure 36). In Tianjin, the industrial and commercial sectors dominate the regional economy; in 2015, their shares in the GRP of Tianjin were 69 % and 22 %, respectively (Figure 36). These are the highest shares among the selected four Chinese regions; the corresponding shares for other selected regions were in 2015 67 % and 18 % (Figure 27), 60 % and 11 % (Figure 30), and 61 % and 20 % (Figure 33) for Guangdong, Hebei and Shandong, respectively.

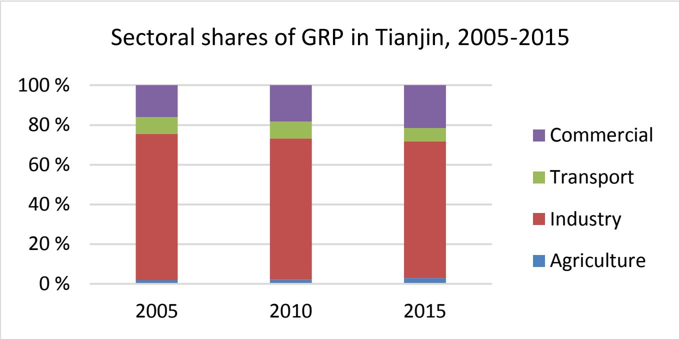

Figure 36. Sectoral shares of GRP in the municipality of Tianjin, 2005-2015.

Table 4. Tianjin: Gross industrial output value of Industry above designated size by sector.

Tianjin: Gross Industrial Output Value of Industry Above Designated Size by Sector	Gross Industrial Output Value (%) of Total 2014
Smelting and Pressing of Ferrous Metals	16
Electronic Equipment	11
Manufacture of Motorcar	7
Mining and Washing of Coal	6
Chemical Products, Manufacture of Food, Manufacture of Metal Products	5 (for each industry separately)
Manufacture of Metal Products, Extraction of Petroleum and Natural Gas, Nuclear Fuel, Manufacture of Special Purpose Machinery, Manufacture of Electrical Machinery and Equipment	4 (for each industry separately)

Source: Tianjin statistical yearbook, 2016

Figure 37 shows that in terms of final energy consumption, Tianjin is a relatively small region in China. During the studied period, industrial and residential final energy consumption has increased rapidly. The commercial sector has increased its share in the regional GRP, but final energy consumption of this sector has decreased. The share of coke and coal has decreased in the industrial energy mix, and it is relatively low in all sectors. However, total consumption of coke and coal in Tianjin has increased from 9.4 to 13 Mtoe during the studied period. Petroleum products are the most important energy carriers in the Tianjin economy. Electricity and heat cover a half of the residential energy consumption, and natural gas is widely used in the commercial sector (wholesale and retail trade and services).

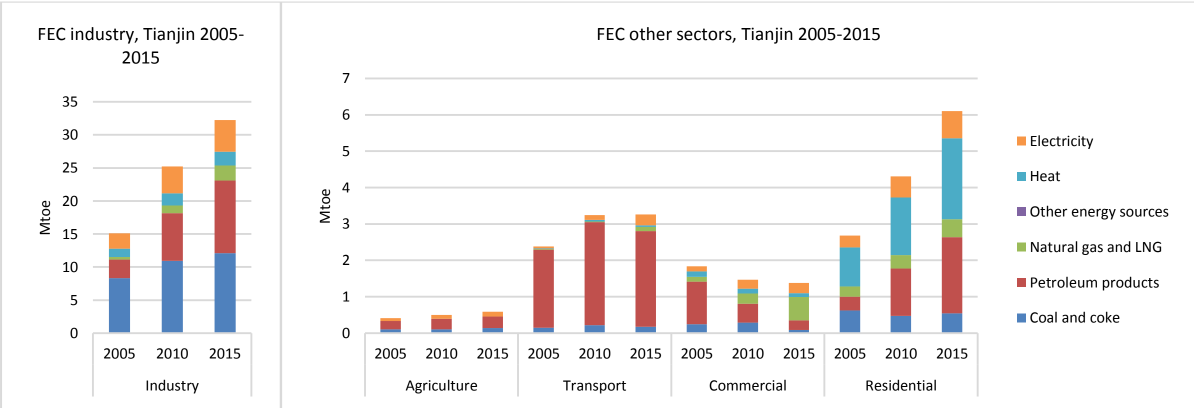

Figure 37. Final energy consumption (FEC) by sector and energy carrier in the Tianjin municipality, 2005-2015.

The decomposition results (Figure 38) show that the drivers GRP/EMP (economic growth, labour productivity), EMP/POP (employment) and POP (population) have all had an increasing effect to both total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2). The driver TPES/FEC (efficiency of the energy transformation system) has a small decreasing effect to both TPES and CO_2, but the despite of the significant decreasing effect of driver FEC/GRP (energy intensity) both TPES and CO_2 emissions have increased significantly in Tianjin. Due to the improved fuel mix and the related decreasing effect of the driver CO_2/TPES during a 10 years period, CO_2 emissions have increased only 42 % while TPES has almost doubled (Figure 38).

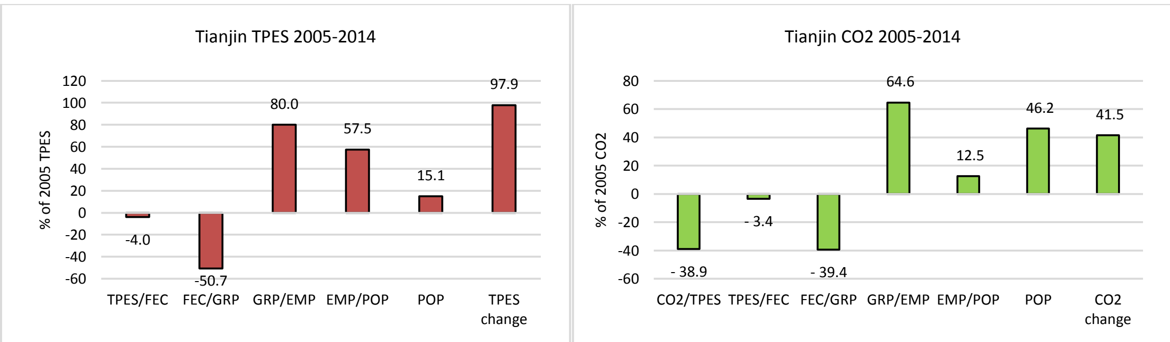

Figure 38. Decomposition of total primary energy supply (TPES) and CO_2 emissions in the Tianjin municipality, 2005-2014.

Conclusions

In this deliverable, results from decomposition analyses of change in total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2) in 20 Chinese administrative regions between the years 2005 and 2014 have been presented. The analysis focused on the (increasing or decreasing) effects of drivers "efficiency of the energy transformation system" (TPES/FEC), "energy intensity" (FEC/GRP), "labour productivity" (GRP/EMP), "employment" (EMP/POP), and "population" (POP), to total primary energy supply. The effects of the same drivers and the driver "carbon intensity" to the change in CO_2 emissions from fuel combustion have been also calculated. Detailed results from incremental decomposition analyses are presented in Annex 1 for TPES and in Annex 2 for CO_2. Summing up the incremental effects the reader has an opportunity to create results for other time periods between the years 2005 and 2014.

Total primary energy supply (TPES) and CO_2 emissions from fuel combustion have increased in all the 20 studied Chinese administrative regions during the studied period 2005-2014, except a 1.2 % decrease in CO_2 emissions in the municipality of Beijing. The increase in percentage varies a lot between the different regions. Some regions have had extremely large increases, for example TPES almost tripled (179 % increase) in the Xinjiang autonomous region and CO_2 emissions have almost quadrupled (283 % increase) in the Hunan province.

The most important driver of TPES and CO_2 emissions in the years 2005-2014 with an increasing effect has been "labour productivity" (GRP/EMP), which has had a significant increasing effect to TPES and CO_2 in all Chinese administrative regions. The driver "employment" (EMP/POP) has increased TPES, and the driver "population" (POP) has increased CO_2 emissions in most of the Chinese regions.

The most important driver of TPES and CO_2 emissions in 2005-2014 with a decreasing effect has been "energy intensity" (FEC/GRP), which has decreased TPES and CO_2 emissions in all administrative regions in China, except the Xinjiang autonomous region. The driver "carbon intensity" (CO_2/TPES) has increased CO_2 emissions in the provinces of Anhui, Guangdong, Jilin, Shaanxi and Shandong, and in the autonomous regions of Inner Mongolia and Xinjiang. In the other 13 Chinese administrative regions, the driver CO_2/TPES has decreased CO_2 emissions. These effects must be considered in the context of the different roles of different regions in the Chinese economy and division of labour. Some regions may produce electricity for the needs of other regions, while some other regions may be more electricity consumers. An example of an electricity producing region is the province of Guangdong.

The driver "efficiency of the energy transformation system" (TPES/FEC) has relatively small effect to total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2) in China. In two administrative regions, the effect of TPES/FEC to TPES and CO_2 can be mentioned: in the province of Shaanxi the driver TPES/FEC has had a decreasing effect to both TPES and CO_2, and in the province of Shanxi the effect of TPES/FEC to TPES and CO_2 ´has been an increasing one.

For the interpretation of the decomposition results, four Chinese administrative regions were taken into further analysis. For analysing the effect of especially two drivers which have a potential to a decreasing effect to both TPES and CO_2 emissions, "carbon intensity" (CO_2/TPES) and "energy intensity” (FEC/GRP), the economic structure and energy mix of the provinces of Guangdong, Hebei and Shandong and the municipality of Tianjin were looked at. The changes in the shares of different sectors in the regional economy (GRP), and the changes in the use of different energy carriers (coal and coke, petroleum products, natural gas and LNG, other energy sources, electricity and heat) in the different economic sectors helped interpretation of the achieved decomposition results.

In the provinces of Guangdong and Shandong, the relative and absolute increase in the use of fossil fuels (coal and coke as well as petroleum products and natural gas) explains the increasing effect of driver CO_2/TPES to CO_2 emissions. In the Hebei province and in the Tianjin municipality, increase in the use of non-fossil energy sources explain the decreasing effect of CO_2/TPES to CO_2 emissions. Correspondingly, change in economic structure, typically increase in the share of the commercial sector and decrease in the share of industry explains the decreasing effect to both total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2) in all four regions taken into further consideration.

Isolating the effect of changing energy technologies is not possible at the regional level analysis (and other analyses using aggregated data), but the effect of changing energy efficiency is included in the effects of drivers TPES/FEC (efficiency of the production of energy carriers from primary energy) and FEC/GRP (decrease in energy consumption of productive economic activities). More disaggregated decomposition analyses, e.g. case studies at the process level, would provide more information about the effects of changing energy technologies. A major challenge for disaggregated analysis is the availability of data and access to it. Further research could also focus on including the economic structure and energy mix in the decomposition analysis at the regional level, and using the drivers of the decomposition analysis also as the drivers of future scenarios.

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Annex 1. Chinese statistics: Standards, comparative analysis, and reliability

Availability or regional fata

There are two relatively independent levels of statistical sources: national level and local level (including provinces and other administrative divisions). National Bureau of Statistics (NBS) collects information not from local provincial authorities, but directly from organizations. Then the information is published on the official webpage with open access. However, the most recent data from the previous year is usually published separately in a National China Statistical Yearbook (中国统计年鉴) and does not have free access. Along with the national information, provinces and other administrative regions have their own statistical yearbooks with more detailed data about local cities and rural areas. Nowadays, China Statistical Yearbooks are important and frequently used sources for academic and other analytical purposes. Although the information is available in the Internet, there are several factors making data gathering complicated and time-consuming, especially on the provincial level.

First of all, not all local statistical yearbooks have the same structure as the national level yearbook, and included data items vary from region to region and from year to year. Secondly, although the statistical data is sometimes organized into time series at the national level and can be easily acquired, at the local level the situation is different. Data has to be gathered from local statistical yearbooks for each year separately. Aggregated data is usually easy to collect, but increasing disaggregation requires more data (IEA 2014), and thus more work, more time and often also more costs. In China this is a very relevant point: For instance, in order to build a 10 years time series of one statistical variable for all 22 provinces, one needs to work with 220 different statistical yearbooks. Moreover, not all the regions provide free access to the local statistics, and some of them need to be purchased. All these factors make data collection and work with China's regional data labour-intensive and time-consuming. Nevertheless, nowadays, the National Bureau of Statistics of China is developing more comprehensive and convenient hierarchical database with both national and local level. However, this information is limited and detailed data can be still acquired only from local statistical yearbooks.

Data modification and unit conversion

Work with China's statistics especially when it comes to international analysis and comparison, requires further data modification and unit conversion. The basic unit of measurement in China is 10 000 (wan, 万), which is used for all types of data including population, economy, and the energy sector, which are on focus in this deliverable. For further global comparative analysis, the data should be transferred to international statistical standards.

On both national and local levels, economic and financial indicators are represented in RMB, the official Chinese currency. China's databases do not contain information transferred into currencies traditionally used for international comparative analysis, such as the United States dollar (USD, US$). Usually, parameters measuring national economy including GDP in US dollar can be obtained from the

International Monetary Fund (IMF) databases and the World Bank. However, when working with the provincial level, the same units obtained from the local databases require further alteration.

According to the National Bureau of Statistics, coal consumption in China has always been relatively high and fluctuates annually around 70 % of the China's total energy consumption. Therefore, coal plays a major role in the entire China's economy and all energy consumption is measured in standard coal equivalent (SCE). For a global comparative analysis, International Energy Agency (IEA) provides China's national energy statistics in tonnes of oil equivalent (toe). However, China's provincial information can be obtained only from provincial statistical yearbooks and requires further modification and unit conversion.

Reliability

Statistical standards are not the only aspect requiring special consideration in Chinese data. Reliability and statistical inconsistencies are common challenges in any work with quantitative socio-economic data. Sometimes it is difficult to find an explanation for tendencies and differences in the data. For instance, total coal consumption in China shows a considerable disparity between data acquired from the national level statistics and the sum of statistics from the provincial sources (Figure A1). Both trends have an upward tendency, but the level of consumption computed from provincial data is clearly higher than the level of consumption reported in the national statistics. Liu (2015) has reported a 20 % difference between figures of coal consumption at the national and provincial levels in his analysis covering the years 2009-2012. After 2012, the gap decreased significantly (Figure A1). One of the possible reasons for the gap may be the fact that provincial authorities have forced local power plant managers to report only part of their statistical information to Beijing (Holz 2013). Other possible reasons for the difference include inaccuracies in data collection and modification, or variety in methods of estimating coal consumption at the provincial and national levels.

Although it is complicated to assume which data reflects better the actual coal consumption tendencies, for the provincial level analysis the local data was chosen. It is frequently reported that emission factors are presumably reduced in China's statistics and the provincial level data seems to be more reliable because it is relatively high in comparison to the national level. On the other hand, time series based on the provincial level data do not show the same dramatic changes as the national level data between 2012 and 2013.

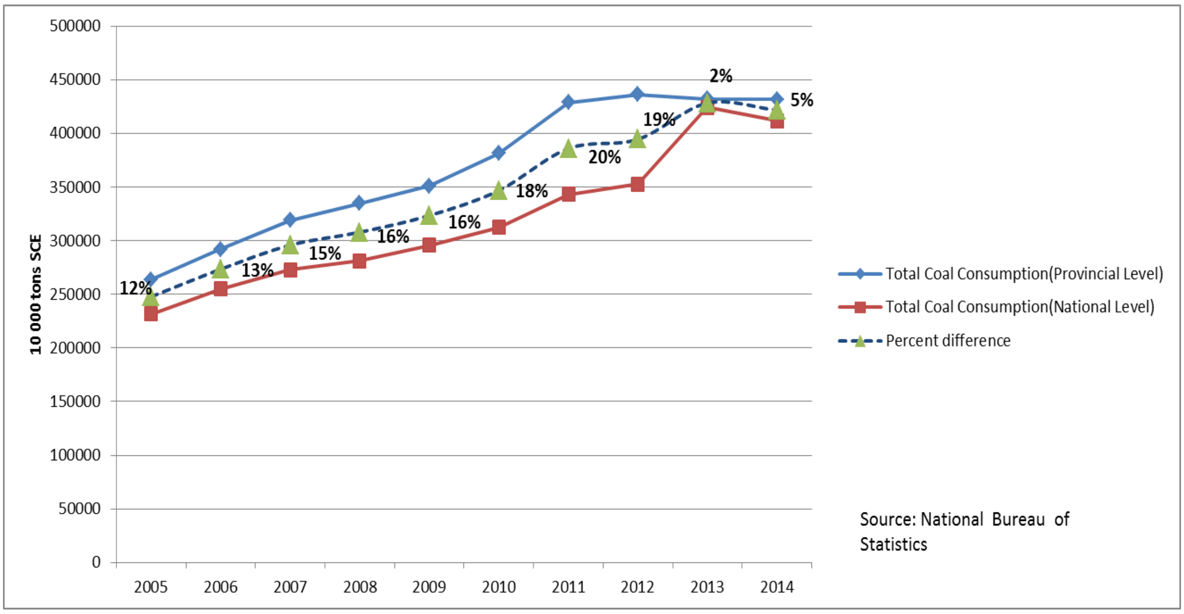

Figure A1. Total consumption of coal in China: Difference between the data acquired from provincial and national level.

Data of the selected four regions

The sectoral data at the regional level includes the following variables for each selected region (Guangdong, Hebei, Shandong, Tianjin): value added in real prices 2010 RMB, final energy consumption and composition by energy carriers, CO_2 emissions and employment by major economic sectors for the years 2005, 2010 and 2015.

Although each Chinese region has a wide range of different industrial branches and manufacturing of many different products, statistical data is usually available only for industrial branches above a designated size. However, the six major economic sectors (agriculture, industry, construction, wholesale and retail trade, transportation, and residence) covers the entire economic activity in China. Construction has been included into industry in the data used in this deliverable.

According to the Chinese NBS documents (Hong, no date), value added is measured from 94 "industries", and summed to obtain annual GDP. Value added for four industries (agriculture, forestry, animal husbandry, and fishing) are calculated by using a production approach. 39 industries of "mining, manufacturing, production and distribution of electricity, gas and water" are calculated by production approach and income approach, and the final estimates are obtained by means of weighting. The remaining 51 industries are calculated by income approach. (Hong, no date.)

In this deliverable, value-added in constant prices 2010 is calculated by using chain method and the available NBS indices of value-added for the primary, secondary and tertiary industries.

Final energy consumption (FEC) for each region was collected from the China's Energy Statistical Yearbook, 2016. Initially, the data is in physical units, and it has been transferred to tons of oil equivalent through conversion factor for each energy carrier separately. In the data, the "petroleum products total" is not equal to a sum of individual petroleum-based fuels. Further calculation of final energy consumption for each sector is based on the variable "petroleum products total", not on individual petroleum-based fuels. Carbon dioxide (CO_2) emissions have been calculated from final energy consumption figures, because no information was available for total primary energy supply (TPES) at the sectoral level. The sectoral data of the selected regions is not used in decomposition analysis; it is only used in interpreting the results of decomposition analysis in the case of the four selected regions carried out without sectoral data.

Annex 2. Results from the incremental decomposition analysis of total primary energy supply (TPES) in 20 Chinese regions, 2005-2014

In the following tables, results from incremental decomposition analysis of total primary energy supply (TPES) in 20 Chinese regions are presented. All the numbers in the tables below are in million tonnes of oil equivalent (Mtoe). The decomposed effects of the drivers "efficiency of the energy transformation system" (TPES/FEC), "energy intensity" (FEC/GRP), "labour productivity" (GRP/EMP), "employment" (EMP/POP) and "population" sum up to the observed TPES change. Positive value of a driver refers to an increasing effect and negative value to a decreasing effect to TPES. Effects in a longer period can be calculated by summing up annual changes. For calculating the changes as percentage from a base year value, the absolute amount of TPES in the first year of each annual change is included in the last column of each table.

Anhui	**TPES/FEC**	**FEC/GRP**	**GRP/EMP**	**EMP/POP**	**POP**	**TPES change (Mtoe)**	**TPES (Mtoe) in the previous year**
2005-2006	-1.2	0.7	3.7	-0.1	1.0	4.1	45.7
2006-2007	0.2	-1.5	4.8	0.1	1.0	4.5	49.7
2007-2008	0.3	-2.7	4.9	0.2	1.3	4.0	54.3
2008-2009	0.0	-3.7	6.7	0.0	1.1	4.0	58.3
2009-2010	-2.2	-3.9	8.4	-1.8	2.8	3.4	62.3
2010-2011	3.3	-4.4	8.3	0.1	1.1	8.4	65.6
2011-2012	-0.3	-0.8	5.0	0.3	1.3	5.5	74.0
2012-2013	-0.6	-1.7	5.8	0.6	0.8	4.9	79.5
2013-2014	-3.7	-2.5	5.3	0.7	0.0	-0.3	84.4

Beijing	**TPES/FEC**	**FEC/GRP**	**GRP/EMP**	**EMP/POP**	**POP**	**TPES change (Mtoe)**	**TPES (Mtoe) in the previous year**
2005-2006	-1.4	-2.0	2.7	1.6	0.2	1.2	38.4
2006-2007	-0.4	-2.2	3.9	1.9	-0.9	2.3	39.6
2007-2008	0.8	-1.8	0.4	2.3	-0.7	1.1	41.9
2008-2009	0.4	-2.5	3.2	2.2	-1.4	1.9	43.0
2009-2010	0.1	-1.7	2.7	2.5	-1.0	2.5	44.9
2010-2011	1.1	-3.0	1.3	1.4	0.4	1.1	47.4
2011-2012	0.5	-1.9	1.5	1.2	0.5	1.7	48.5
2012-2013	0.0	-7.0	2.4	1.1	0.4	-3.1	50.3
2013-2014	-0.2	-2.3	2.4	0.8	-0.2	0.6	47.1

Chongqing	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.0	-0.1	2.7	0.1	-0.1	2.5	30.5
2006-2007	0.1	-0.3	3.4	0.1	0.2	3.5	33.1
2007-2008	-0.3	3.3	5.2	0.3	0.3	8.8	36.5
2008-2009	0.7	-2.5	5.0	0.3	0.3	3.9	45.3
2009-2010	0.3	-1.5	6.1	0.5	0.4	5.8	49.2
2010-2011	0.2	-2.8	7.4	0.7	1.0	6.6	55.0
2011-2012	-0.9	-2.0	4.4	0.6	1.3	3.4	61.5
2012-2013	1.3	-15.4	3.6	0.5	1.3	-8.6	64.9
2013-2014	-2.4	0.4	5.3	0.4	0.1	3.8	56.3

Fujian	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-0.2	2.8	2.9	0.3	1.5	7.4	40.3
2006-2007	0.1	-1.1	4.7	0.4	1.3	5.3	47.7
2007-2008	-0.1	0.0	3.0	0.4	1.3	4.7	53.0
2008-2009	-0.2	-0.5	5.0	0.5	2.1	6.8	57.6
2009-2010	-1.0	-7.3	6.0	0.5	1.7	-0.1	64.4
2010-2011	1.7	1.7	0.3	0.5	5.9	10.2	64.3
2011-2012	-0.2	-2.4	3.1	0.6	2.7	3.7	74.6
2012-2013	-0.9	-5.3	6.7	0.5	-0.9	0.0	78.3
2013-2014	-0.1	-0.4	4.0	0.7	2.2	6.4	78.3

Guangdong	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-0.2	-3.8	12.9	3.5	0.5	12.9	125.4
2006-2007	-0.1	-0.3	10.9	3.3	1.2	15.0	138.4
2007-2008	-0.2	-3.6	8.1	3.8	0.0	8.1	153.4
2008-2009	-0.9	0.1	5.3	4.0	2.5	11.1	161.5
2009-2010	0.5	0.3	11.3	5.5	0.2	17.8	172.6
2010-2011	-1.3	-2.9	10.3	1.2	1.8	9.0	190.4
2011-2012	0.7	-14.9	7.4	1.7	-1.5	-6.6	199.4
2012-2013	0.1	-6.6	8.2	0.9	4.0	6.6	192.7
2013-2014	0.6	-7.3	12.4	1.5	0.6	7.8	199.4

Hebei	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-0.1	-0.6	12.8	1.0	0.7	13.7	138.9
2006-2007	0.1	-3.2	13.2	1.0	1.4	12.5	152.6
2007-2008	-1.0	-9.2	12.6	1.1	1.6	5.2	165.1
2008-2009	1.2	-6.4	9.8	1.1	2.0	7.7	170.3
2009-2010	-11.2	-3.0	16.3	4.1	-0.6	5.5	177.9
2010-2011	1.5	0.8	15.9	1.3	3.6	23.1	183.4
2011-2012	0.7	-5.7	3.9	1.4	5.1	5.3	206.5
2012-2013	16.7	-1.8	4.6	1.4	3.9	24.8	211.8
2013-2014	-16.4	-5.0	4.3	1.6	-0.6	-16.0	236.5

Hubei	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.0	-1.3	7.4	-0.2	0.8	6.8	70.6
2006-2007	0.2	-3.1	10.1	0.1	0.4	7.7	77.3
2007-2008	-0.9	-4.9	10.2	0.2	0.4	4.9	85.0
2008-2009	0.9	-7.4	12.2	0.1	0.2	6.0	89.9
2009-2010	2.1	-7.2	14.4	0.1	0.5	10.0	96.0
2010-2011	-2.9	-1.4	13.5	0.6	0.2	10.1	106.0
2011-2012	0.3	-3.8	10.7	0.4	0.1	7.7	116.1
2012-2013	0.4	-24.1	9.7	0.4	-0.2	-13.8	123.7
2013-2014	-0.5	-5.2	10.1	0.3	-0.5	4.3	109.9

Hunan	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-1.6	-0.6	7.5	0.2	0.6	6.1	68.0
2006-2007	0.4	-3.4	9.5	0.2	0.7	7.3	74.1
2007-2008	0.0	-5.9	10.4	0.3	0.2	5.1	81.4
2008-2009	0.0	-4.2	10.5	0.4	0.2	6.8	86.5
2009-2010	-1.0	-2.8	13.2	2.5	-1.3	10.6	93.3
2010-2011	-1.4	-3.2	13.2	0.4	0.2	9.2	104.0
2011-2012	0.1	-6.1	9.7	0.7	-0.3	4.1	113.1
2012-2013	1.4	-23.3	8.6	0.9	-0.4	-12.8	117.2
2013-2014	-0.9	-5.2	8.6	0.7	-0.5	2.8	104.4

Inner Mongolia	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.6	-4.1	13.6	0.4	0.3	10.8	66.5
2006-2007	-1.4	-3.3	13.3	0.5	1.9	11.0	77.3
2007-2008	-0.8	-9.8	17.5	0.6	1.3	8.7	88.3
2008-2009	0.1	-2.3	10.5	0.6	3.0	11.9	97.0
2009-2010	7.7	-13.3	9.7	0.6	3.5	8.2	108.9
2010-2011	-4.3	2.2	9.5	0.5	6.1	14.0	117.2
2011-2012	6.9	-8.9	3.5	0.4	5.4	7.3	131.2
2012-2013	-6.7	6.7	-5.2	0.5	10.3	5.7	138.4
2013-2014	8.1	-5.2	-3.6	0.4	9.0	8.7	144.1

Jiangsu	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-0.4	-3.6	13.6	1.1	0.2	11.0	120.2
2006-2007	-0.3	0.9	13.4	1.2	0.3	15.4	131.2
2007-2008	-0.1	-6.6	14.9	0.8	0.0	9.0	146.6
2008-2009	-0.1	-6.7	16.3	1.0	-0.1	10.3	155.6
2009-2010	2.6	-9.8	20.6	1.3	-0.3	14.5	166.0
2010-2011	-5.7	-5.4	16.9	0.7	-0.6	5.9	180.4
2011-2012	-0.6	-3.2	12.2	0.5	-0.5	8.5	186.3
2012-2013	-5.3	-0.3	15.2	0.5	-0.5	9.7	194.7
2013-2014	0.9	-11.8	15.5	0.5	-0.5	4.6	204.4

Jiangxi	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.2	-1.8	3.6	0.2	0.4	2.6	29.9
2006-2007	0.0	-1.0	3.1	0.2	0.5	2.8	32.6
2007-2008	-0.4	-1.4	3.6	0.3	0.3	2.3	35.3
2008-2009	-0.2	-0.5	3.0	0.3	0.4	3.0	37.6
2009-2010	0.4	-3.5	5.5	0.3	0.6	3.3	40.7
2010-2011	-0.8	-1.0	5.7	0.3	0.4	4.5	44.0
2011-2012	-0.4	-0.9	3.0	0.2	0.3	2.1	48.5
2012-2013	0.6	-2.5	3.7	0.2	0.5	2.5	50.6
2013-2014	-0.1	-0.8	3.9	0.2	0.1	3.3	53.1

Jilin	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.0	-1.1	5.3	0.1	0.3	4.7	41.7
2006-2007	0.1	-1.8	6.2	0.1	0.5	5.1	46.4
2007-2008	0.0	-1.5	6.1	0.1	0.6	5.2	51.4
2008-2009	1.2	-11.0	6.3	0.1	0.6	-2.8	56.7
2009-2010	0.6	-3.8	5.8	0.1	0.5	3.3	53.9
2010-2011	-0.4	-0.4	6.1	0.0	1.2	6.6	57.2
2011-2012	-0.1	-3.5	5.0	0.0	0.9	2.3	63.7
2012-2013	-0.1	-3.1	1.5	0.0	2.8	1.2	66.1
2013-2014	-0.3	-9.6	1.5	0.0	1.4	-7.0	67.2

Qinghai	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-0.2	0.0	1.6	0.1	0.0	1.6	11.7
2006-2007	0.0	-0.6	1.7	0.1	0.1	1.4	13.3
2007-2008	0.2	-1.6	2.5	0.1	0.1	1.3	14.7
2008-2009	-0.1	-0.4	0.9	0.1	0.0	0.5	15.9
2009-2010	0.2	-1.5	2.6	0.2	0.1	1.5	16.4
2010-2011	0.1	1.2	2.6	0.2	-0.1	4.0	18.0
2011-2012	-0.2	0.3	2.0	0.2	-0.1	2.3	22.0
2012-2013	0.1	-0.4	2.0	0.2	0.0	2.0	24.3
2013-2014	-0.5	0.1	1.7	0.2	0.0	1.6	26.4

Shaanxi	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-8.4	-6.4	8.5	0.1	0.2	-6.0	61.0
2006-2007	-1.0	-1.1	6.2	0.1	0.6	4.9	54.9
2007-2008	0.6	-5.2	9.8	0.2	0.6	5.9	59.8
2008-2009	-3.4	-0.1	6.8	0.2	0.5	4.0	65.7
2009-2010	-9.0	-3.6	10.2	0.1	0.3	-1.9	69.7
2010-2011	-3.8	-0.4	10.0	0.2	-0.7	5.3	67.8
2011-2012	-2.0	-1.5	8.5	0.2	-0.1	5.0	73.1
2012-2013	-1.1	-2.4	7.4	0.2	-0.4	3.7	78.1
2013-2014	-0.4	-2.6	6.0	0.2	0.2	3.5	81.8

Shandong	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	1.4	-7.7	21.3	1.2	2.4	18.6	169.4
2006-2007	1.1	-2.6	13.8	1.2	2.7	16.3	187.9
2007-2008	-1.9	-12.2	19.6	1.1	2.5	9.1	204.2
2008-2009	0.5	-8.5	16.4	1.2	2.5	12.2	213.4
2009-2010	-0.1	-5.1	15.9	2.9	1.1	14.7	225.6
2010-2011	-5.6	-32.1	13.0	1.2	1.8	-21.8	240.3
2011-2012	-6.2	1.7	12.4	1.1	1.2	10.3	218.5
2012-2013	0.4	-7.3	16.8	1.2	-0.2	10.8	228.8
2013-2014	-3.9	-3.6	14.4	1.4	-0.4	7.9	239.6

Shanxi	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	-2.4	-1.5	21.3	1.9	10.9	30.2	306.9
2006-2007	13.0	-20.7	41.7	1.9	5.9	41.8	337.1
2007-2008	19.2	-37.7	43.9	2.1	2.4	30.0	378.8
2008-2009	-34.0	10.5	-1.6	1.9	2.2	-21.0	408.9
2009-2010	39.6	-39.9	55.3	17.8	-3.7	69.1	387.8
2010-2011	17.4	-20.0	44.5	2.6	12.4	56.9	456.9
2011-2012	-9.0	4.8	7.6	2.6	12.6	18.5	513.8
2012-2013	6.0	9.7	-4.8	2.9	13.4	27.2	532.4
2013-2014	-5.2	-1.9	-7.0	2.7	2.7	-8.7	559.5

Sichuan	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.2	-3.0	10.7	-0.5	0.7	8.0	82.7
2006-2007	0.2	-3.6	11.3	-0.5	0.8	8.2	90.8
2007-2008	0.1	-3.9	10.6	0.1	0.1	7.1	99.0
2008-2009	1.3	-5.9	12.4	0.6	-0.2	8.2	106.0
2009-2010	-2.4	-2.8	15.8	-2.1	2.5	11.0	114.3
2010-2011	-9.6	5.9	16.0	0.1	0.3	12.6	125.2
2011-2012	2.5	-9.8	13.1	0.5	-0.1	6.2	137.9
2012-2013	1.3	-21.5	10.1	0.5	0.0	-9.5	144.0
2013-2014	1.7	-6.3	8.8	0.6	-0.1	4.7	134.5

Tianjin	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.0	0.0	1.8	0.9	0.2	2.9	28.8
2006-2007	-0.1	0.1	0.1	1.2	1.7	2.9	31.7
2007-2008	-0.4	-3.1	4.4	1.9	0.0	2.9	34.6
2008-2009	0.0	-0.9	2.7	1.7	0.1	3.6	37.5
2009-2010	0.0	0.3	3.2	2.5	0.8	6.7	41.1
2010-2011	-1.5	-0.8	4.0	2.1	0.2	4.0	47.7
2011-2012	0.3	-1.3	2.6	2.3	0.5	4.4	51.7
2012-2013	0.7	-6.7	2.0	2.3	0.7	-1.0	56.1
2013-2014	0.0	-2.3	2.3	1.7	0.2	1.8	55.2

Xianjing	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.0	-0.5	3.7	0.8	0.2	4.3	37.4
2006-2007	1.3	0.2	2.2	1.0	0.0	4.7	41.7
2007-2008	0.4	-1.6	3.9	0.8	0.2	3.6	46.4
2008-2009	0.7	1.5	0.0	0.7	0.4	3.3	49.9
2009-2010	1.4	-6.7	8.3	0.7	1.1	4.7	53.2
2010-2011	-0.6	4.5	3.5	0.7	3.3	11.4	57.9
2011-2012	-1.1	7.4	2.8	0.8	3.6	13.6	69.3
2012-2013	-0.4	4.7	1.1	1.2	6.1	12.6	82.8
2013-2014	-0.5	1.2	4.9	1.5	2.0	9.1	95.4

Yunnan	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	TPES change (Mtoe)	TPES (Mtoe) in the previous year
2005-2006	0.0	-4.4	3.5	0.3	0.6	0.0	42.2
2006-2007	-0.1	3.3	3.9	0.3	0.7	8.1	42.2
2007-2008	0.9	-3.5	4.1	0.3	0.9	2.8	50.2
2008-2009	-1.5	0.2	3.5	0.3	0.6	3.2	53.0
2009-2010	0.7	-2.0	4.0	0.4	1.3	4.5	56.2
2010-2011	0.7	-3.0	6.2	0.4	1.7	6.1	60.7
2011-2012	-0.6	-1.3	7.5	0.4	0.2	6.3	66.8
2012-2013	-2.3	-0.2	7.9	0.5	0.3	6.2	73.0
2013-2014	-0.1	-11.2	4.0	0.4	0.9	-6.0	79.2

Annex 3. Results from incremental decomposition analysis of CO_2 emissions in 20 Chinese regions, 2005-2014

In the following tables. results from incremental decomposition analysis of carbon dioxide emissions from fuel combustion (CO_2) in 20 Chinese regions are presented. All the numbers in the tables below are in million tonnes of CO_2 (Mtons). The decomposed effects of the drivers "carbon intensity" (CO_2/TPES), "efficiency of the energy transformation system" (TPES/FEC), "energy intensity" (FEC/GRP), "labour productivity" (GRP/EMP), "employment" (EMP/POP) and "population" sum up to the observed CO_2 change. Positive value of a driver refers to an increasing effect and negative value to a decreasing effect to CO_2. Effects in a longer period can be calculated by summing up annual changes. For calculating the changes as percentage from a base year value, the absolute amount of CO_2 emissions in the first year of each annual change is included in the last column of each table.

Anhui	**CO_2/TPES**	**TPES/FEC**	**FEC/GRP**	**GRP/EMP**	**EMP/POP**	**POP**	**CO_2 change (Mtons)**	**CO_2 (Mtons) in the previous year**
2005-2006	-5.9	-6.4	3.6	18.9	5.1	-0.4	14.9	236.7
2006-2007	4.3	0.9	-7.8	24.6	5.1	0.3	27.5	251.6
2007-2008	24.5	1.6	-14.2	26.5	6.8	0.8	46.0	279.1
2008-2009	14.0	-0.1	-21.3	37.9	6.5	-0.2	36.7	325.1
2009-2010	1.8	-12.6	-22.4	48.8	16.5	-10.8	21.4	361.9
2010-2011	-12.6	18.9	-25.4	47.7	6.2	0.7	35.5	383.2
2011-2012	-18.0	-1.6	-4.5	27.9	7.4	1.4	12.6	418.7
2012-2013	3.4	-3.0	-9.0	31.6	4.2	3.1	30.1	431.3
2013-2014	8.7	-20.6	-14.0	29.0	-0.3	4.1	6.8	461.4

Beijing	**CO_2/TPES**	**TPES/FEC**	**FEC/GRP**	**GRP/EMP**	**EMP/POP**	**POP**	**CO_2 change (Mtons)**	**CO_2 (Mtons) in the previous year**
2005-2006	1.8	-3.8	-5.6	7.6	0.7	4.4	5.2	107.3
2006-2007	-4.1	-1.1	-6.1	10.9	-2.4	5.2	2.4	112.5
2007-2008	-3.6	2.3	-5.0	1.2	-1.8	6.3	-0.6	114.9
2008-2009	-3.5	1.0	-6.5	8.3	-3.6	5.6	1.4	114.3
2009-2010	-4.4	0.3	-4.4	6.7	-2.4	6.2	2.1	115.7
2010-2011	-8.8	2.6	-7.3	3.2	0.9	3.3	-6.1	117.8
2011-2012	-1.8	1.1	-4.4	3.3	1.1	2.8	2.1	111.6
2012-2013	2.3	0.1	-15.9	5.4	0.9	2.5	-4.8	113.7
2013-2014	-4.3	-0.4	-5.2	5.4	-0.4	1.9	-3.0	108.9

Chongqing	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	3.7	-0.1	-0.2	9.5	-0.5	0.4	12.6	106.7
2006-2007	-0.8	0.2	-1.2	12.2	0.9	0.4	11.7	119.3
2007-2008	2.9	-1.1	11.9	18.8	1.2	1.2	34.8	131.1
2008-2009	0.2	2.7	-9.2	18.4	1.2	1.2	14.5	165.9
2009-2010	-0.3	1.2	-5.7	22.3	1.6	1.7	20.8	180.3
2010-2011	2.0	0.9	-10.3	27.3	3.7	2.5	26.1	201.2
2011-2012	-21.6	-3.2	-6.9	15.5	4.7	2.0	-9.6	227.3
2012-2013	5.4	4.4	-52.3	12.3	4.5	1.8	-23.8	217.7
2013-2014	-2.9	-8.2	1.5	18.2	0.2	1.4	10.1	193.9

Fujian	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	-11.4	-0.7	10.2	10.6	5.5	1.2	15.4	150.3
2006-2007	5.5	0.2	-3.9	16.5	4.6	1.3	24.2	165.7
2007-2008	-4.5	-0.3	-0.1	10.7	4.7	1.5	12.0	189.9
2008-2009	-8.1	-0.7	-1.8	17.0	7.2	1.5	15.2	201.9
2009-2010	7.7	-3.3	-25.1	20.7	5.7	1.6	7.3	217.1
2010-2011	13.3	6.2	6.1	1.2	21.3	1.8	49.9	224.4
2011-2012	-19.1	-0.8	-8.6	10.9	9.7	2.0	-5.8	274.3
2012-2013	-7.8	-3.1	-18.1	22.7	-3.2	1.8	-7.7	268.5
2013-2014	-16.3	-0.3	-1.2	13.0	7.2	2.2	4.5	260.8

Guangdong	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	3.9	-0.5	-10.1	34.6	1.3	9.4	38.6	335.7
2006-2007	10.1	-0.3	-0.8	29.7	3.4	9.1	51.2	374.3
2007-2008	2.5	-0.5	-9.9	22.5	0.1	10.4	25.1	425.5
2008-2009	-4.6	-2.5	0.4	14.8	7.0	11.0	26.1	450.6
2009-2010	9.8	1.3	0.9	31.6	0.6	15.3	59.5	476.8
2010-2011	50.6	-4.0	-8.6	30.3	5.3	3.5	77.1	536.2
2011-2012	2.5	2.0	-45.8	22.8	-4.6	5.1	-18.0	613.3
2012-2013	-37.4	0.4	-19.7	24.5	12.0	2.8	-17.5	595.3
2013-2014	-19.9	1.6	-20.9	35.3	1.8	4.3	2.3	577.9

Hebei	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	-32.7	-0.4	-2.5	52.1	2.7	4.1	23.1	581.8
2006-2007	39.2	0.4	-13.1	54.1	5.6	4.2	90.4	604.9
2007-2008	-24.8	-4.3	-37.9	52.1	6.8	4.6	-3.5	695.3
2008-2009	26.4	5.0	-26.6	40.5	8.2	4.6	58.2	691.9
2009-2010	10.0	-47.6	-12.9	69.1	-2.7	17.3	33.2	750.1
2010-2011	-1.5	6.2	3.6	68.0	15.2	5.4	97.0	783.3
2011-2012	-3.7	2.9	-24.3	16.5	21.5	5.8	18.7	880.3
2012-2013	-90.4	67.4	-7.2	18.5	15.9	5.6	9.8	899.0
2013-2014	6.7	-63.3	-19.3	16.8	-2.2	6.1	-55.2	908.8

Hubei	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	5.1	0.1	-4.8	27.9	2.9	-0.8	30.5	261.9
2006-2007	2.5	0.8	-12.0	38.5	1.4	0.3	31.6	292.4
2007-2008	-23.3	-3.3	-18.1	37.4	1.4	0.7	-5.2	324.0
2008-2009	6.8	3.3	-26.6	43.6	0.9	0.5	28.4	318.8
2009-2010	20.7	7.8	-26.7	53.8	1.9	0.5	58.0	347.2
2010-2011	27.8	-11.4	-5.4	53.4	0.9	2.3	67.6	405.2
2011-2012	-26.5	1.1	-15.2	42.6	0.2	1.7	3.9	472.8
2012-2013	-44.0	1.3	-88.2	35.7	-0.9	1.5	-94.6	476.7
2013-2014	-17.4	-1.7	-17.5	34.4	-1.6	1.1	-2.8	382.2

Hunan	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	-1.2	-5.8	-2.3	28.2	2.2	0.7	21.6	255.0
2006-2007	-2.2	1.6	-12.7	35.3	2.5	0.6	25.2	276.6
2007-2008	-22.2	0.0	-21.2	37.3	0.9	1.2	-4.1	301.8
2008-2009	-4.7	0.0	-14.4	35.7	0.7	1.3	18.6	297.7
2009-2010	-16.8	-3.2	-9.2	43.7	-4.3	8.2	18.4	316.3
2010-2011	19.2	-4.7	-10.5	43.5	0.6	1.4	49.5	334.7
2011-2012	-36.8	0.4	-19.8	31.3	-1.1	2.4	-23.6	384.2
2012-2013	20.8	4.3	-73.8	27.4	-1.3	2.8	-19.8	360.7
2013-2014	-15.2	-2.8	-16.5	27.5	-1.7	2.3	-6.3	340.9

Inner Mongolia	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	2.7	3.4	-24.4	81.8	2.0	2.2	67.7	397.9
2006-2007	3.3	-8.2	-19.9	80.4	11.3	2.9	69.9	465.6
2007-2008	50.6	-4.9	-62.4	110.9	8.1	3.6	106.0	535.5
2008-2009	-23.1	0.8	-15.0	68.3	19.5	3.8	54.4	641.5
2009-2010	32.3	50.5	-86.9	63.2	22.6	4.2	86.0	695.9
2010-2011	110.1	-30.5	15.6	67.8	43.3	3.6	209.9	781.9
2011-2012	-3.8	51.8	-67.4	26.1	41.0	3.3	50.9	991.7
2012-2013	-93.8	-48.0	48.6	-37.4	74.3	3.3	-53.1	1042.7
2013-2014	-18.5	55.3	-35.6	-24.7	61.1	2.8	40.5	989.6

Jiangsu	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	6.6	-1.5	-14.8	55.8	1.0	4.6	51.7	488.4
2006-2007	-16.6	-1.3	3.7	54.3	1.0	4.9	46.0	540.1
2007-2008	-6.9	-0.3	-26.1	59.1	-0.1	3.0	28.8	586.2
2008-2009	-31.6	-0.3	-26.0	62.7	-0.5	3.8	8.3	615.0
2009-2010	11.4	10.0	-37.3	78.1	-1.0	4.9	66.1	623.3
2010-2011	100.4	-23.5	-22.3	69.2	-2.3	2.9	124.5	689.4
2011-2012	-17.0	-2.6	-13.9	52.9	-2.0	2.2	19.6	813.8
2012-2013	-35.5	-22.0	-1.3	63.9	-1.9	2.0	5.1	833.4
2013-2014	-41.2	3.5	-47.3	62.1	-2.0	2.2	-22.7	838.5

Jiangxi	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	-1.0	1.0	-7.8	15.4	1.7	0.9	10.1	126.9
2006-2007	3.6	-0.2	-4.3	13.3	2.0	1.0	15.4	137.0
2007-2008	-6.9	-1.6	-6.0	15.1	1.1	1.1	2.9	152.4
2008-2009	-9.5	-0.8	-1.8	12.1	1.5	1.1	2.6	155.3
2009-2010	15.6	1.7	-14.4	22.4	2.6	1.2	29.0	157.9
2010-2011	2.8	-3.2	-4.3	24.3	1.5	1.2	22.3	186.9
2011-2012	-12.0	-1.9	-3.7	12.6	1.2	0.7	-3.1	209.2
2012-2013	7.1	2.5	-10.2	15.1	1.9	0.9	17.2	206.1
2013-2014	-6.8	-0.4	-3.2	16.0	0.3	1.0	6.9	223.4

Jilin	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	0.3	0.1	-5.1	25.3	1.4	0.5	22.6	199.3
2006-2007	-12.2	0.4	-8.5	29.0	2.2	0.6	11.6	221.9
2007-2008	-12.3	-0.1	-6.5	26.8	2.5	0.4	10.8	233.5
2008-2009	19.8	5.6	-49.2	28.1	2.5	0.5	7.4	244.3
2009-2010	14.4	3.0	-18.0	27.9	2.2	0.7	30.1	251.7
2010-2011	8.3	-1.8	-1.9	30.6	5.8	0.2	41.1	281.8
2011-2012	-9.4	-0.3	-17.3	25.0	4.2	0.1	2.3	322.9
2012-2013	-24.9	-0.4	-14.5	6.9	13.5	0.1	-19.4	325.2
2013-2014	32.8	-1.5	-46.3	7.3	6.7	0.1	-1.0	305.8

Qinghai	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	2.4	-0.3	0.1	3.6	0.0	0.3	6.1	25.1
2006-2007	0.9	0.1	-1.3	4.0	0.2	0.2	4.1	31.2
2007-2008	5.3	0.5	-4.1	6.5	0.2	0.1	8.6	35.3
2008-2009	-0.8	-0.2	-1.1	2.3	0.1	0.2	0.5	43.9
2009-2010	-5.0	0.6	-3.8	6.5	0.2	0.5	-1.1	44.4
2010-2011	-0.9	0.2	3.0	6.2	-0.2	0.4	8.7	43.3
2011-2012	5.7	-0.4	0.8	5.1	-0.2	0.5	11.5	52.0
2012-2013	1.0	0.4	-1.0	5.3	0.1	0.6	6.4	63.5
2013-2014	-10.8	-1.1	0.2	4.1	0.1	0.6	-7.0	69.9

Shaanxi	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	61.7	-29.3	-22.4	29.6	0.5	0.5	40.6	181.0
2006-2007	-0.5	-3.9	-4.5	24.9	2.6	0.6	19.1	221.6
2007-2008	10.0	2.4	-21.3	40.0	2.6	0.7	34.4	240.7
2008-2009	0.2	-14.1	-0.6	28.6	2.2	0.7	16.9	275.1
2009-2010	70.7	-42.1	-17.1	48.2	1.5	0.7	61.8	292.0
2010-2011	20.1	-20.4	-2.0	53.6	-3.6	0.8	48.5	353.8
2011-2012	39.6	-11.6	-8.9	48.7	-0.7	1.2	68.3	402.3
2012-2013	15.6	-7.0	-14.9	45.1	-2.1	1.4	38.1	470.6
2013-2014	10.5	-2.3	-16.3	37.5	1.5	1.5	32.5	508.7

Shandong	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	24.8	6.3	-34.4	94.6	10.8	5.2	107.4	741.2
2006-2007	3.3	5.2	-11.7	62.3	12.4	5.5	77.0	848.6
2007-2008	33.0	-8.6	-56.3	90.3	11.6	5.1	75.2	925.6
2008-2009	-40.0	2.5	-39.0	75.5	11.6	5.7	16.2	1000.8
2009-2010	12.0	-0.5	-23.2	72.2	4.8	13.1	78.5	1017.0
2010-2011	158.3	-27.4	-157.7	63.6	8.9	5.7	51.5	1095.5
2011-2012	-9.2	-32.3	9.0	65.0	6.5	5.8	44.8	1147.0
2012-2013	-144.3	2.0	-35.5	82.1	-1.1	5.7	-91.2	1191.8
2013-2014	16.1	-17.8	-16.5	66.4	-2.0	6.5	52.6	1100.6

Shanxi	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	4.4	-5.6	-3.4	49.4	25.4	4.4	74.6	711.5
2006-2007	-69.4	29.0	-46.3	93.2	13.2	4.3	24.0	786.0
2007-2008	-74.8	39.3	-77.0	89.8	5.0	4.3	-13.5	810.0
2008-2009	28.4	-67.5	20.9	-3.1	4.3	3.7	-13.3	796.5
2009-2010	-74.7	76.4	-77.0	106.7	-7.1	34.3	58.7	783.2
2010-2011	-5.2	32.0	-36.8	81.7	22.9	4.7	99.3	841.9
2011-2012	-2.9	-16.5	8.7	13.8	23.0	4.8	31.0	941.3
2012-2013	9.1	11.1	17.9	-8.9	24.5	5.3	58.9	972.3
2013-2014	42.5	-9.9	-3.6	-13.1	5.0	5.2	26.2	1031.2

Sichuan	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	3.0	0.5	-9.3	32.5	2.1	-1.4	27.5	249.8
2006-2007	4.7	0.6	-11.2	34.8	2.5	-1.5	29.9	277.3
2007-2008	15.3	0.4	-12.3	33.7	0.2	0.4	37.7	307.2
2008-2009	20.3	4.3	-19.6	41.6	-0.8	2.1	47.9	344.9
2009-2010	-40.2	-7.8	-9.1	51.6	8.1	-6.8	-4.3	392.8
2010-2011	-38.0	-28.4	17.3	47.4	0.8	0.2	-0.7	388.6
2011-2012	-2.9	7.0	-27.5	36.7	-0.2	1.3	14.3	387.9
2012-2013	29.0	3.7	-62.3	29.4	0.0	1.6	1.4	402.2
2013-2014	-26.7	4.9	-18.3	25.6	-0.3	1.6	-13.1	403.6

Tianjin	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	-10.0	-0.2	-0.1	7.0	0.8	3.6	1.1	116.8
2006-2007	-6.0	-0.5	0.3	0.4	6.0	4.4	4.7	117.9
2007-2008	-7.0	-1.4	-10.5	15.2	0.0	6.6	2.9	122.6
2008-2009	-6.1	0.1	-2.9	8.8	0.2	5.6	5.7	125.5
2009-2010	0.1	-0.1	0.9	10.1	2.4	8.0	21.4	131.2
2010-2011	1.6	-4.8	-2.5	12.8	0.6	6.7	14.5	152.5
2011-2012	-9.9	0.9	-4.0	8.2	1.5	7.1	3.9	167.0
2012-2013	1.6	2.1	-20.4	6.1	2.2	7.0	-1.3	171.0
2013-2014	-9.9	-0.1	-7.0	6.8	0.7	5.0	-4.4	169.6

Xinjiang	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	4.2	0.1	-1.8	13.3	0.8	2.8	19.2	130.5
2006-2007	-0.5	4.7	0.6	8.0	0.2	3.4	16.3	149.7
2007-2008	6.7	1.3	-6.0	14.1	0.6	3.0	19.7	166.0
2008-2009	32.6	2.7	5.9	0.2	1.8	2.7	45.8	185.7
2009-2010	2.3	5.9	-29.5	36.1	5.0	2.9	22.7	231.5
2010-2011	-0.7	-2.6	19.6	15.1	14.6	3.0	49.1	254.3
2011-2012	5.9	-4.7	32.5	12.5	15.9	3.6	65.8	303.3
2012-2013	12.1	-1.9	21.1	4.9	27.4	5.6	69.2	369.1
2013-2014	18.8	-2.2	5.6	22.8	9.2	7.0	61.2	438.2

Yunnan	CO_2/TPES	TPES/FEC	FEC/GRP	GRP/EMP	EMP/POP	POP	CO_2 change (Mtons)	CO_2 (Mtons) in the previous year
2005-2006	23.5	0.0	-21.8	17.1	3.2	1.5	23.5	196.5
2006-2007	-33.0	-0.7	15.9	19.0	3.4	1.5	6.2	220.0
2007-2008	-3.1	4.1	-15.8	18.5	4.2	1.5	9.5	226.1
2008-2009	12.9	-6.7	1.1	15.8	2.8	1.5	27.4	235.7
2009-2010	-3.3	3.4	-9.3	18.7	6.3	1.8	17.6	263.1
2010-2011	-16.5	3.3	-13.4	28.1	7.5	1.8	10.8	280.8
2011-2012	-18.9	-2.4	-5.6	31.8	0.8	1.8	7.5	291.5
2012-2013	-28.7	-9.0	-0.7	30.8	1.3	1.8	-4.6	299.0
2013-2014	-6.8	-0.4	-41.2	14.7	3.2	1.6	-29.0	294.5