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Abstract

In 2010, China was responsible for nearly 20 percent of global energy use and 25 percent of energy-related carbon dioxide (CO_2) emissions. Unlike most countries, China's energy consumption pattern is unique because the industrial sector dominates the country's total energy consumption, accounting for about 70 percent of energy use and 72 percent of CO_2 emissions in 2010. For this reason, the development path of China's industrial sector will greatly affect future energy demand and dynamics of not only China, but the entire world. A number of analyses of historical trends have been conducted, but careful projections of the key factors affecting China's industry sector energy use over the next decade are scarce. This study analyzes industrial energy use and the economic structure of the Chinese manufacturing sector in detail. First, the study analyzes the energy use of and output from 18 industry sub-sectors. Then, retrospective (1995-2010) and prospective (2010-2020) decomposition analyses are conducted for these industrial sectors in order to show how different factors (production growth, structural change, and energy intensity change) influenced industrial energy use trends in China over the last 15 years and how they will do so over the next 10 years.

The historical analysis results show that top energy-consuming subsectors such as smelting and pressing of ferrous metals, raw chemical materials and chemical products manufacturing, and non-metallic mineral product manufacturing use more energy per value added and comprise a large share of Chinese manufacturing primary energy use while having a much lower share of total manufacturing value added in 2010. In contrast, the electric and electronic equipment manufacturing, food, beverage and tobacco industry, and machinery manufacturing accounted for more than 1/3 of manufacturing value added while only consuming 8 percent of total Chinese manufacturing primary energy in 2010.

The decomposition analysis shows that both energy intensity reduction and changes in structure contributed to the reduction in energy use in Chinese manufacturing during the periods 1995-2000 and 2005-2010. In all years, the activity effect increased overall energy use. Also in all years, the intensity effect reduced overall energy consumption, providing a counter-balance to the increased energy use due to increased activity. The structural effect also reduced overall energy consumption except during the period 2000-2005 when it caused an increase in manufacturing energy use primarily because the share of value added from top energy-intensive sectors like smelting and pressing of ferrous metals from total manufacturing value added increased during this period. The intensity effect during the 10th FYP (2001-

2005) is the smallest and slightly decreased primary energy use compared to the other periods with larger intensity effects. This was due to a very small decline in overall manufacturing energy intensity during this period because the energy intensity of some manufacturing subsectors, especially the top five energy-intensive manufacturing subsectors (except smelting and pressing of ferrous metals), either remained relatively steady or even increased in some cases.

The forward looking (prospective) decomposition analyses are conducted for three different scenarios. The three scenarios are defined based on different predicted average annual growth rates (AAGR) for value added for different manufacturing subsectors. The value added AAGRs in scenario 1 are mainly based on those provided by Chinese sources. In scenario 2 the value added AAGRs are based on Oxford Economics forecasts. In scenario 3 the value added AAGRs are based on expert judgment.[1] The analysis for 2010-2020 shows that the activity effect is largest under scenario 1 because of the higher value added AAGRs assumed for manufacturing subsectors under this scenario. The structural effect, however, is largest in scenario 3 because the share of value added of energy-intensive subsectors such as smelting and pressing of ferrous metals and non-metallic mineral products sectors in total manufacturing value added in 2015 and 2020 are lower in scenario 3 compared to the other two scenarios.

The scenario analysis indicates that if China wants to realize structural change in the manufacturing sector by shifting from energy-intensive and polluting industries to less energy-intensive industries, the value added AAGRs to 2015 and 2020 should be more in line with those shown in scenario 3. The assumed value added AAGRs for scenario 3 are relatively realistic and are informed by possible growth that is foreseen for each subsector. Such structural change is also a result of shifts in demand for manufactured products. The government can influence demand for manufactured products indirectly, but only to some extent, and generally only temporarily. Hence, in addition to government policies in the past, the industrial structural change in China we have analyzed in this study are also caused by broad macroeconomic trends such as where a country is on the development path, emerging demand trends, and the country's economic comparative advantage in meeting different types of demand.

The results of this study will allow policy makers to quantitatively compare the level of structural change in the past and in the years to come and adjust their policies if needed to move towards the target of less energy-intensive industries. The scenario analysis shows the structural change achieved through different paths and helps to understand the consequences of supporting or limiting the growth of certain manufacturing subsectors from the point of view of energy use and structural change. The results point out the industries that have the largest influence in such structural change.

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[1] The expert judgment is that of the authors, Bob Taylor (formerly of World Bank), and colleagues at China’s Energy Research Institute and is based on the sources of information used for scenarios 1 and 2 as well as their knowledge of Chinese policies and discussions with experts from a number of Chinese industrial associations.

Contents

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1. Introduction

In the last three decades, China has experienced unprecedented rapid economic growth with annual gross domestic product (GDP) growing at an average rate of 10 percent from 1980 to 2010 (NBS, 1981-2011). China became the world's largest emitter of energy-related CO_2 in 2007 and the world's largest energy consumer in 2009 (IEA, 2011). In 2010, China was responsible for nearly 20 percent of global energy use and 25 percent of energy-related CO_2 emissions followed by the U.S. who is responsible for 18 percent of global energy use and 18 percent of global energy-related CO_2 emissions in 2010 (IEA, 2011).

Unlike most countries, China's energy consumption pattern is unique because the industrial sector dominates the country's total energy consumption, accounting for about 70 percent of energy use and 72 percent of CO_2 emissions[2] in 2010 (NBS, 2011a). For this reason, the development path of China's industrial sector will greatly affect future energy demand and dynamics of not only China, but the entire world.

China's industrialization relies heavily on energy-intensive industries such as the iron and steel industry, the cement industry, non-ferrous metals, etc. This is mostly because of the massive amount of construction and infrastructure building during the last three decades. However, for many reasons such as energy scarcity and energy security, environmental concerns, and the relatively developed stage of urbanization and infrastructure building in the eastern regions China would like to see more structural change away from polluting energy-intensive industries to less-polluting and non-energy intensive industries .The Chinese government intensified its structural change policy in the 11th Five-Year-Plan (FYP) (2006-2010) and in the current 12th FYP (2011-2015). China aimed to increase the share of GDP from the tertiary sector[3] to 43.3 percent during the 11th FYP. By end of 2010, the share of tertiary sector in total GDP increased to 43.0 percent. However, contrary to the plan, the share of heavy industries in total industrial value added increased from 68.1 percent to 70.9 percent during the period 2006-2010. In the 12th FYP, China's goal is to increase the share of tertiary sector in national GDP by 4 percentage points compared to its share at the end of 2010 (Chinese Government Website, 2011, 2012).

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[2] Carbon dioxide emissions were estimated based on reported energy data multiplied by IPCC default emission factors (NBS, 2011a; IPCC, 1996).

[3] The tertiary sector in China includes all other sectors that are not included in primary sector (farming, fishing, agriculture, forestry, etc.) and secondary sector (mining & quarrying, manufacturing and utilities supply). Hence, tertiary sector includes residential, commercial, transport, hotels, other services, etc.

A number of analyses of historical industrial energy use trends in China have been conducted (Wu 2012; Price et al. 2011; Wang et al. 2010; Ma and Stern 2008; Liu et al. 2007; Lin et al. 2006), but comprehensive analyses including all manufacturing subsectors and their role in historical energy use trends are scarce. More importantly, in the context of this study, careful projections of key factors affecting China's manufacturing sector energy use over the next decade are also rare. This study conducts such analyses.

Energy-to-GDP ratios have been widely used internationally to measure the energy efficiency performance of national economies, until a body of research exposed the limits of using this indicator (Schipper et al. 1992; Patterson 1993; Ang and Lee 1994; and IEA 2004). Energy analysts demonstrated that factors other than energy intensity were also affecting changes in energy use; mainly the overall level of aggregate activity (the activity effect), and the composition of various activities within the economy (the structure effect). Techniques for factorization or decomposition analysis were developed to isolate the energy intensity effect in order to give a better estimate of energy efficiency improvements. Ang (2004) provides a complete review of the different aspects and evolution of these techniques. Ultimately, the more the effects affecting energy use are isolated the better is the estimate of energy intensity effect. However, available data to allow factorizing additional components of the decomposition analyses can be limited.

In 1997, the journal *Energy Policy* devoted a complete issue on the subject of decomposition analysis (vol 25, issue 7-9). For Schipper et al. (1997; 2001), energy indicators describe the link between energy consumption and human activity. Several authors refer to an energy indicators pyramid to help conceptualize the level of energy efficiency considered (Worrell et al., 1997; Phylipsen et al., 1998; Schipper et al., 1997; APERC, 2001). With each level of desegregation of indicators constructed, it is possible to isolate additional effects that influence energy consumption.

This study first analyzes China's past manufacturing energy use trends and also makes projections for manufacturing energy use and value added up to 2020 for each manufacturing sub-sector. Then, it uses decomposition analysis to quantify the effects of various factors in shaping energy consumption trends in the past and in the near future. Decomposition analysis has been employed by many energy analysts since the early 1990s. By indexing certain drivers to a base year value, this analysis approach shows how energy consumption would have changed had all other factors been held constant. Decomposition analysis is used to understand the drivers of energy use as well as to measure and monitor the performance of energy-related policies. The unique feature of decomposition analysis is that it provides macro results based on myriad detailed energy indicators. This gives policy makers quick access to findings from technical data. Most countries of the Organization for Economic Cooperation and Development (OECD) use decomposition analysis to understand their energy use and assess the progress of their energy policies. Reviews of decomposition analysis used at the national and international level include de la Rue du Can et al. (2010) and Liu and Ang (2003).

Decomposition of past trends helps modelers to accurately project future changes in energy use. For example, decomposition allows separate modeling of structural and intensity trends and combining of their effects to improve the accuracy of estimates of future energy demand. Projection and decomposition of future trends will help analyst and policy makers to estimate how the energy use will change over years in the future and how much of the change re likely the result of energy efficiency policies and how much from structural change policies. This can help them to adjust their policies if needed to meet the certain target (e.g. 12th FYP energy intensity reduction target in China).

This paper presents an analysis of energy use and value added trends of the Chinese manufacturing sector in the past, assumptions and future projections of energy use and value added for each manufacturing sub-sector, and a decomposition analysis to quantify the effects of various factors in shaping the trends in manufacturing energy consumption in the past and the near future up to 2020.

2. Methodology

Table 1 lists the manufacturing subsectors included in this study. We collected energy use and value added data as well as other information on 18 subsectors of the manufacturing sector in China from 1995 to 2010.[4]

Table 1. List of Manufacturing Subsectors Included in this Study

No.	Manufacturing subsector
1	Food, beverage and tobacco
2	Textile, Apparel, Chemical Fibers, Leather, Fur
3	Timber, Wood, Bamboo, etc.
4	Furniture
5	Paper and Paper Products
6	Printing and Publishing
7	Petroleum refining and Coking
8	Raw Chemical Materials and Chemical Products
9	Medicines
10	Rubber and Plastics
11	Non-metallic Mineral Products
12	Smelting and Pressing of Ferrous Metals
13	Smelting and Pressing of Non-ferrous Metals
14	Metal Products
15	Machinery
16	Transport Equipment
17	Electric and Electronic Equipment
18	Other industries

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[4] In Chinese statistics, the term “industry” refers to manufacturing as well as mining of coal and minerals, oil and gas extraction, power generation, and production and distribution of water. These subsectors of industry (other than manufacturing) are not included in the present study.

2.1. Forecasting Chinese manufacturing energy use and value added

Historical primary energy use (1995 – 2010) and value added (1995 – 2007) data for industrial subsectors used this analysis were obtained from various years of the *China Energy Statistical Yearbook* (NBS, 1996-2011) and the *Annual China Industry Economy Statistical Yearbook* (NBS, 1981-2011), respectively.

For primary energy use reported by NBS (1996-2011), electricity use is converted from final to primary energy using the average power generation efficiency in China in various years. The losses in refining of petroleum products and for production of coke are not included in the primary energy values reported by NBS (1996-2011) .

Value added data for manufacturing subsectors have not been reported since 2007. Thus, value added for 2008-2010 for manufacturing subsectors was calculated using the officially released annual average growth rate of value added for manufacturing subsectors for these three years (NBS 2009, 2010, 2011b). The sum of value added of all manufacturing subsectors calculated in this way for these three years is equal to the aggregate data reported in NBS (1981-2011). All value added data are converted from current RMB to constant 2005 RMB and then used in the analyses.

1. We forecast primary energy use and value added of manufacturing subsectors in 2015 and 2020 in this analysis. To forecast primary energy use, we need to have the forecast of value added as well as energy intensity. From these two, we can calculate the forecast of primary energy use from equation 1.

   $$\mathbf{E_i = EI_i * VA_i} \qquad \mathbf{(1)}$$

   Where:
   E_i : primary energy use of manufacturing subsector (i) [in PJ]
   EI_i : primary energy intensity of manufacturing subsector (i) [in PJ/Million 2005 RMB]
   VA_i : value added of manufacturing subsector (i) [Million 2005 RMB]

Below we explain how the value added and energy intensity of each manufacturing subsector in 2015 and 2020 are forecast.

2. The year 2010 is used as the base year for the forecast. We have primary energy use and value added data for each manufacturing subsector in 2010.
3. The forecast of primary energy use and value added is calculated for each manufacturing subsector separately. This is one of the unique features of this study since other similar studies typically constructed a forecast for the entire manufacturing sector in China and not by manufacturing subsector.
4. Because the forecast for the average annual growth rate (AAGR) given for each manufacturing subsector value added varied in different sources and since the forecast of value added significantly affects the results of the study, we developed three scenarios with different assumptions on the AAGR of value added for each manufacturing subsector. The three scenarios are:

a. Scenario 1 (MIIT/IERD/ERI/INNET): In this scenario the value added AAGR assumptions were mostly based on *Key Development Targets for 22 Industries During the 12th FYP* published by the Chinese Ministry of Industry and Information Technology (MIIT 2012a-n; MIIT 2011a-g) and the report by the Industrial Economics Research Department, Development Research Center of the State Council, (IERD), Energy Research Institute of the National Development and Reform Commission (ERI), Institute of Nuclear and New Energy Technology, Tsinghua University (INNET) titled *2050 China Energy and* CO_2 *Emissions Report* (IERD/ ERI/ INNET 2009).

b. Scenario 2 (Oxford Economics): In this scenario the assumptions on value added AAGR were mostly based on the Oxford Economics' *China Industry Forecast* (Oxford Economics 2012).

c. Scenario 3 (Expert Judgment): In this scenario the assumptions on value added AAGR were mostly based on expert judgment. The expert judgment was informed by national level GDP forecast data and the predicted share of total GDP of the industry sector in the national GDP in 2015 and 2020 as well as by the data used in scenario 1 and scenario 2. In particular scenario 3 tends to take into account the Chinese Government policy to shift the structure of industry away from heavy and energy-intensive industries toward lighter and less energy-intensive industries with higher value added as well as the policy to "rebalance" the economy, which focuses on greater reliance on domestic demand, as opposed to new fixed-asset investment and exports, to drive economic growth.

Table 2 shows the value added AAGR assumptions used in our analysis under each of the aforementioned scenarios. Under each scenario, there are two sets of AAGR assumptions, one for the period of 2011-2015 (12th FYP) and the other for the period of 2016-2020 (13th FYP). Table 2 also presents the energy intensity AAGR for each subsector. Unlike the value added assumptions, only one set of assumptions is used for the energy intensity AAGR forecast.

5. Having the value added AAGR during 2011-2015 (12th FYP) compared to 2010 value added (Table 2) and the actual 2010 value added data for manufacturing subsectors, we calculated the value added of each manufacturing in 2015 using equation 2.

$$\mathbf{VA_{i\,(2015)} = VA_{i\,(2010)} * (1+AAGR_{2011\text{-}2015})^5} \qquad \mathbf{(2)}$$

Where:
$VA_{i\,(2015)}$: value added of manufacturing subsector (i) in 2015
$VA_{i\,(2010)}$: value added of manufacturing subsector (i) in 2010
$AAGR_{2011\text{-}2015}$: average annual growth rate of manufacturing subsector (i) during 2011-2015

Table 2. Value added AAGR assumptions used under each scenario and primary energy intensity AAGR forecasts

No.	**Manufacturing subsector**	**Value added AAGR ***						**Primary energy intensity cumulative reduction rate over 5-year ****	
		Scenario 1		**Scenario 2**		**Scenario 3**			
		AAGR in 2011-2015	**AAGR in 2016-2020**	**AAGR in 2011-2015**	**AAGR in 2016-2020**	**AAGR in 2011-2015**	**AAGR in 2016-2020**	**Cumulative reduction rate over 2011-2015**	**Cumulative reduction rate over 2016-2020**
1	Food, beverage and tobacco	9.0%	7.0%	7.9%	6.1%	8.0%	7.0%	16.0%	14.0%
2	Textile, Apparel, Chemical Fibers, Leather, Fur	7.0%	5.5%	5.3%	4.8%	6.0%	5.0%	18.0%	15.0%
3	Timber, Wood, Bamboo, etc.	9.0%	7.0%	11.5%	6.2%	9.0%	7.0%	16.0%	14.0%
4	Furniture	9.0%	6.6%	9.4%	7.0%	9.0%	7.0%	16.0%	13.0%
5	Paper and Paper Products	8.0%	6.7%	8.3%	6.9%	7.5%	7.0%	20.0%	16.0%
6	Printing and Publishing	8.0%	8.0%	6.6%	8.4%	7.0%	8.0%	16.0%	14.0%
7	Petroleum refining and Coking	7.5%	6.0%	7.5%	5.7%	7.0%	6.0%	20.0%	16.0%
8	Raw Chemical Materials and Chemical Products	12.0%	9.0%	10.5%	9.7%	9.5%	8.5%	20.0%	16.0%
9	Medicines	15.0%	10.0%	13.8%	8.9%	12.0%	10.0%	21.0%	17.0%
10	Rubber and Plastics	7.0%	7.0%	6.5%	6.5%	6.5%	6.5%	16.0%	14.0%
11	Non-metallic Mineral Products	8.0%	6.0%	6.4%	6.8%	3.5%	3.0%	15.0%	13.0%
12	Smelting and Pressing of Ferrous Metals	7.0%	5.7%	6.6%	5.4%	4.5%	4.0%	18.0%	15.0%
13	Smelting and Pressing of Non-ferrous Metals	7.0%	6.0%	6.8%	6.2%	6.2%	5.5%	16.0%	14.0%
14	Metal Products	10.0%	7.4%	12.3%	8.7%	10.0%	7.8%	16.0%	14.0%
15	Machinery	10.0%	7.0%	12.1%	8.2%	10.0%	8.0%	16.0%	14.0%
16	Transport Equipment	9.5%	7.0%	9.2%	7.3%	9.0%	7.5%	16.0%	14.0%
17	Electric and Electronic Equipment	11.0%	9.0%	10.5%	8.5%	10.0%	8.5%	16.0%	14.0%
18	Other industries	8.0%	7.0%	8.1%	7.0%	8.0%	7.0%	16.0%	14.0%

* Value added AAGR for 2011-2015 are compared to 2010 value added and for 2016-2020 are compared to 2015 value added (see equation 2 and 3 below).

* Energy intensity cumulative reduction rate over 2011-2015 are compared to 2010 energy intensity and over 2016-2020 are compared to 2015 energy intensity (see equation 4 and 5 below).

*** 2011-2015 period is equal to 12th FYP and 2016-2020 period is 13th FYP in Chinese Government national policy planning.

6. Having calculated the value added of manufacturing subsectors in 2015 from equation 1 and the assumed value added AAGR during 2016-2020 (13th FYP) compared to 2015 value added (Table 2), we calculated the value added of each manufacturing in 2020 using equation 3.

$$\mathbf{VA_{i\,(2020)} = VA_{i\,(2015)} * (1+AAGR_{2016\text{-}2020})^5} \qquad \mathbf{(3)}$$

Where:
$VA_{i\,(2020)}$: value added of manufacturing subsector (i) in 2020
$VA_{i\,(2015)}$: value added of manufacturing subsector (i) in 2015
$AAGR_{2016\text{-}2020}$: average annual growth rate of manufacturing subsector (i) during 2016-2020

The value added for each manufacturing subsector was calculated under each scenario separately using different AAGR assumptions given in Table 2 for each scenario. It should be noted that all value added data and their shares presented in this report are in constant 2005 prices; thus, the shares of value added given for manufacturing or each subsector might be slightly different from the shares calculated using value added data in current prices.

7. The assumptions on primary energy intensity reduction of manufacturing subsectors were mostly based on the forecast given in *Key Development Targets for 22 Industries during 12th FYP* published by the Chinese Ministry of Industry and Information Technology (MIIT 2012a-n; MIIT 2011a-g). Some subsectors (e.g. smelting and pressing of non-ferrous metals, manufacturing of metal products, manufacturing of machinery, and manufacturing of transport equipment) were not included in this report (MIIT 2012a-n; MIIT 2011a-g). For these subsectors China's overall national cumulative energy intensity reduction target during 12th FYP set by the Chinese government, which is 16 percent compared to the 2010 level, is used.[5] However, all reduction forecasts are for cumulative percentage reduction in energy intensity for each manufacturing sub-sector during 2011-2015 (12th FYP). To forecast the energy intensity of manufacturing sub-sectors in 2020, expert judgment is used for the assumption on cumulative reduction of energy intensity during 2016-2020. The primary energy intensities in 2015 and 2020 are calculated using equations 4 and 5, respectively.

$$\mathbf{EI_{i\,(2015)} = EI_{i\,(2010)} * (1 - CR_{2011\text{-}2015})} \qquad \mathbf{(4)}$$

$$\mathbf{EI_{i\,(2020)} = EI_{i\,(2015)} * (1 - CR_{2016\text{-}2020})} \qquad \mathbf{(5)}$$

Where:
$EI_{i\,(2010)}$: primary energy intensity of manufacturing subsector (i) in 2010
$EI_{i\,(2015)}$: primary energy intensity of manufacturing subsector (i) in 2015
$EI_{i\,(2020)}$: primary energy intensity of manufacturing subsector (i) in 2020
$CR_{2011\text{-}2015}$: cumulative reduction energy intensity of manufacturing (i) during 2011-2015 in percentage (the sign is positive)
$CR_{2016\text{-}2020}$: cumulative reduction energy intensity of manufacturing (i) during 2016-2020 in percentage (the sign is positive)

8. Having the forecast of value added and primary energy intensity calculated for each manufacturing subsector, we can calculate the primary energy use of each subsector in 2015 and 2020 using equation 1. Since we calculated value added for three different scenarios, we will also have three scenarios for the primary energy use forecast.

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[5] The 16 percent reduction in energy intensity for these subsectors during 12th FYP is rather a conservative assumption. However, if the energy intensity reduction in this period is assumed to be 20 percent instead for these subsectors, the impact on the overall manufacturing primary energy use is minimal (around 1 percent decrease compared to 16 percent assumption) because these subsectors cumulatively only represent less than 20 percent of the total manufacturing primary energy use.

2.2. Decomposition analysis method

A decomposition analysis separates the effects of key components on energy end-use trends over time. Three main components that are usually considered in a decomposition analysis are: 1) aggregate activity, 2) sectoral structure, and 3) energy intensity. The IEA defines these three components as (Unander et al., 2004):

1. *Aggregate activity*: Depending on the economic sector, this component is measured in different ways. For manufacturing, it is often measured as value added of the sector.
2. *Sectoral structure*: This component represents the mix of activities within a sector and further divides activity into subsectors.
3. *Energy intensity*: This component refers to energy use per unit of activity (i.e. value added).

Different studies have used different mathematical techniques for decomposition analysis. Liu and Ang (2003) explain eight different methods for decomposing the aggregate energy intensity of industry into the impacts associated with aggregate activity, sectoral structure, and energy intensity. They argue that the choice of method can be influenced by limitations such as the data set (e.g., whether or not there are negative values) and the number of factors in the decomposition.

Ang et al. (2010) propose the use of the Logarithmic Mean Divisia Index (LMDI) method, which is recognized as superior in comparative studies such as Liu and Ang (2003). One of the LMDI method's main advantages compared to other widely used decomposition methods such as the Laspeyres method is that LMDI leaves no residual term, which in other methods can be large and affect the results and their interpretation. Two types of decomposition can be performed with LMDI: additive and multiplicative (Ang, 2005). The additive LMDI approach is easier to use and interpret, and its graphical results show effects in a clearer way than is the case for multiplicative analysis. The LMDI method can also be used for both changing and non-changing analysis. Changing analysis is based on yearly evaluations, and non-changing analysis is based on evaluation for a base-year period and an end-year period. For this study, the authors used additive LMDI decomposition analysis with non-changing analysis. Non-changing decomposition is used because for future projections changing analysis (which requires annual data) is less relevant and non-changing analysis with a 5-year period is more appropriate since the AAGR forecast of value added for manufacturing sub-sectors is given in 5-year terms. The energy intensity reduction forecasts are also cumulative over the 5-year periods.

Ang (2005) provides practical guidelines for using the LMDI method. The formulas used in the additive LMDI method for decomposing energy use into activity, structural, and energy intensity effects are shown below (Ang, 2005):

$$\Delta E_{tot} = E^{T} - E^{0} = \Delta E_{act} + \Delta E_{Str} + \Delta E_{int} \qquad (6)$$

$$\Delta E_{act} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - E^0{}_i} \ln(\frac{Q^T}{Q^0}) \quad (7)$$

$$\Delta E_{Str} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - E^0{}_i} \ln(\frac{S^T{}_i}{S^0{}_i}) \quad (8)$$

$$\Delta E_{int} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - E^0{}_i} \ln(\frac{I^T{}_i}{I^0{}_i}) \quad (9)$$

Where:
i: subsector
T: last year of the period
T=0: base year of the period
E: total energy consumption
ΔE_{tot}: aggregate change in total energy consumption

The subscripts "act," "str," and "int" denote the effects associated with the overall activity level, structure, and sectoral energy intensity, respectively.

$$Q = \sum_i Q_i \text{ : total activity level} \quad (10)$$

$$S_i = \sum_i Q_i / Q \text{ : activity share of sector I} \quad (11)$$

$$I_i = \sum_i E_i / Q_i \text{: energy intensity of sector I} \quad (12)$$

In decomposition analysis, energy intensity is often calculated based on economic output. This is because such analysis requires that the energy intensity and output of different manufacturing subsectors be added together (see Equation 3-7); to make this addition possible, the same unit must be used for the output of all subsectors. Moreover, data on physical output can prove challenging to gather for all industrial subsectors.

In this study we conduct a retrospective decomposition analysis of China's manufacturing sector using historical data from 1995 to 2010. In addition, we conduct a prospective decomposition analysis using forecast data calculated based on the method explained above.

We conducted the decomposition analysis for each of the three scenarios explained in section 2.1., separately. This shows how different assumptions regarding the value added AAGR of manufacturing subsectors will affect the decomposition results.

3. Results and Discussion

In this section, we first present an analysis of historical as well as forecasted energy use and value added of Chinese manufacturing subsectors. Then, retrospective and prospective decomposition analysis results are presented.

3.1. Chinese manufacturing energy use and value added

3.1.1. Industry value-added trends

China is the world's second largest economy after the United States. In 2010, China's manufacturing value added was equal to 10,935 billion 2005 RMB[6] accounting for around 35 percent of China's total gross domestic product (GDP) that year[7] (NBS, 1981-2011). The total Chinese manufacturing value added (in 2005 RMB) increased by 383 percent over the period 1995-2010. This rate of increase is 2.8 times higher than the rate of increase in primary energy use, which increased by 137 percent over the same period. Smelting and pressing of non-ferrous metals had the largest increase in value added during 1995-2010 with an 808 percent increase, while petroleum refining, coking, processing of nuclear fuel had the lowest increase in value added among all other subsectors with only 183 percent during the same period. Overall, the value added of all subsectors increased during this period.

Figure 1 shows that electric and electronic equipment manufacturing, food and beverage production, and the textile industry had the highest value added during the period 1995-2010. Figure 2 shows that these sectors thus have the largest contribution to the total manufacturing value added in that period. Manufacturing of furniture, printing and publishing, and processing of timber, manufacturing of wood, bamboo, etc. subsectors have the lowest share of total manufacturing value added.

Between 1995 and 2010, there was no major shift between shares of value added among the subsectors. However, even a minor few percentage change in the share of value added of high energy-intensive sectors (e.g. smelting and pressing of ferrous metals) or low energy-intensive sectors (e.g. electric and electronic equipment manufacturing) can have significant impact in decomposition analysis, especially on the structural effect. This is discussed in more detail in section 3.2.

Table 3 shows the total manufacturing value added AAGR and share of manufacturing value added from China's total GDP under each scenario. It shows that scenario 1 has the highest AAGR for overall manufacturing value added, whereas scenario 3 has the lowest AAGR for manufacturing value added. This is clearly the result of value added AAGR assumed for manufacturing subsector under these two scenarios. Another interesting observation is that the share of manufacturing value added from China's total GDP is increasing under scenario 1

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[6] Using the exchange rate of 6.8 RMB/US$, this will be equal to US$1,608 billion.

[7] It should be noted that manufacturing does not include power generation, mining, and several other sectors that are often included under "industry" sector in Chinese statistics. We refer you to Table 1 for the list of subsectors included in the manufacturing sector in this analysis.

and scenario 2 and is decreasing under scenario 3 at the end of both periods. The results for scenario 3 are more in line with China's national policy to reduce the share of manufacturing from China's total GDP during the 12th FYP and the 13th FYP.

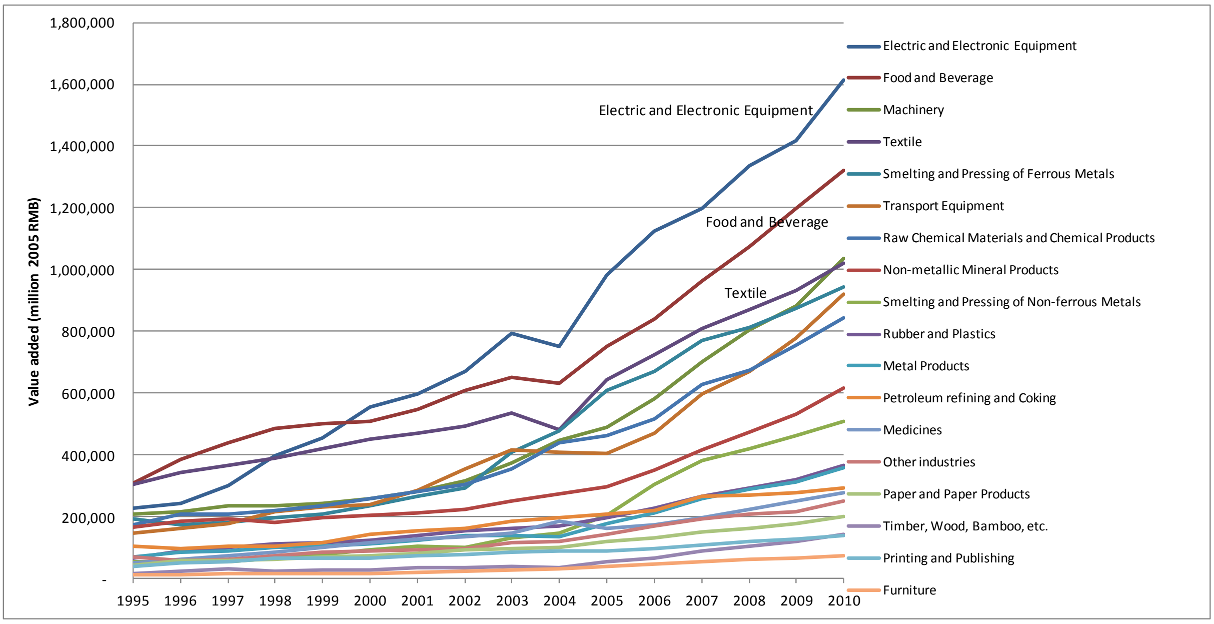
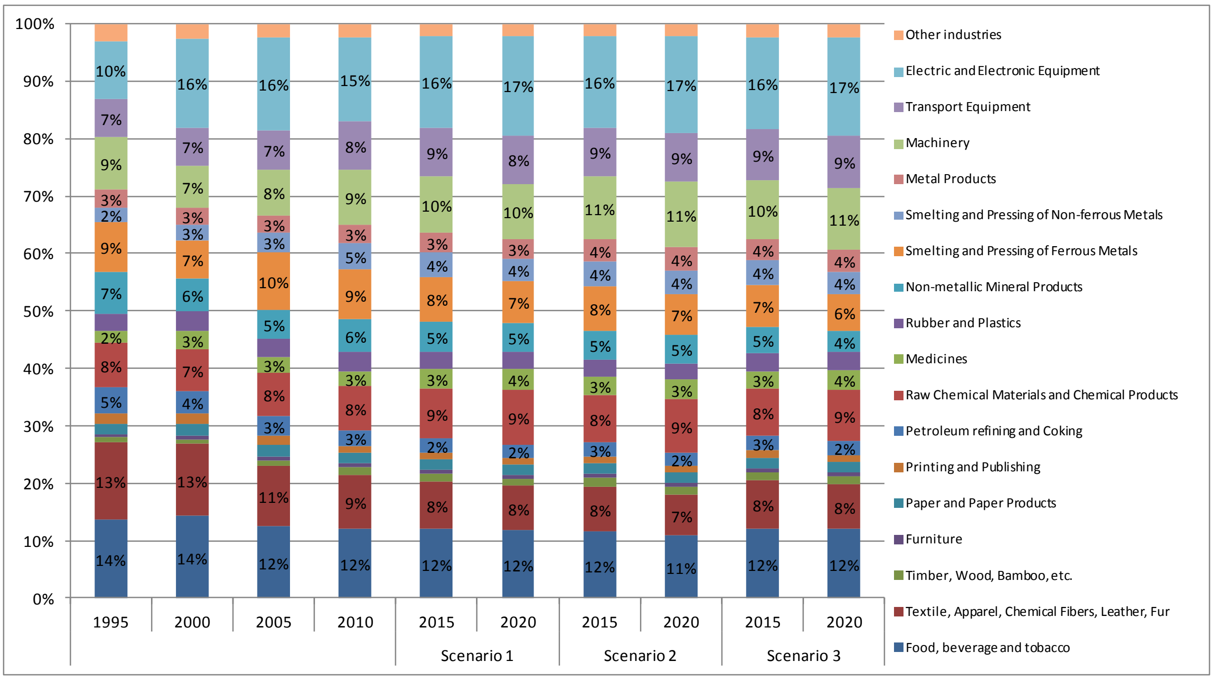


Figure 1. Value added (million 2005 RMB) of different manufacturing subsectors in China, 1995-2010 (NBS, 1981-2011)



Note: All value added data and their shares presented in this report are in constant 2005 prices; thus, the shares of value added given for manufacturing or each subsector might be slightly different from the shares calculated using value added data in current prices.

Figure 2. Share of each manufacturing subsector value added of the total value added of manufacturing in China, 1995-2010 (NBS, 1981-2011)

Table 3. Total manufacturing value added AAGR under each scenario and share of manufacturing value added from China's total GDP*

	Historical	Scenario 1		Scenario 2		Scenario 3	
	2005-2010	2011-2015	in 2016-2020	2011-2015	in 2016-2020	2011-2015	in 2016-2020
Total manufacturing value added AAGR	12.8%	9.2%	7.3%	8.9%	7.3%	8.0%	7.0%
Share of manufacturing value added from China's total GDP* by end of the period (i.e. 2010, 2015, or 2020) **	34.8%	35.8%	36.3%	35.2%	35.7%	33.9%	33.9%

* China's total GDP in 2015 and 2020 is calculated by taking China's total GDP in 2010 (in 2005 constant prices) and assuming the AAGR for China's total GDP of 8.6 percent during 2011-2015 compared to the 2010 level and 7 percent during 2016-2020 compared to the 2015 level. It worth mentioning that the AAGR for China's total GDP during 2006-2010 was 11.2 percent compared to the 2005 level.

****** All value added data and their shares presented in this report are in constant 2005 prices; thus, the shares of value added given for manufacturing or each subsector might be slightly different from the shares calculated using value added data in current prices.

Underlying the manufacturing value added AAGR trends are the demand drivers for Chinese manufactured products. During 2000-2010 strong growth in exports and in fixed asset investment (infrastructure, housing, and new production capacity) drove much of the boom in manufactured product output, although growth in domestic consumption also was important. For example, during 2001-2010, the demand drivers mentioned above drove steel production (in tonnes) to increase by about five times and cement production by more than three times. As a result, China's industrial economy in 2010 did not have the same character and balance as in the more mature large industrial countries. Some economists consider this only a part of the long-term transition of China to a more mature industrialized economy. Also, some experts believe that natural limitations on how much growth can be derived from increasing manufactured exports and large increases every year in infrastructure and fixed asset investment have been peaked.[8] For the future, continued growth from increasing domestic consumption is possible especially because China's per capita consumption of relatively high-value added manufactured goods is still low compared to the per capita consumption of such goods in the developed countries. In the future, less demand pull from increases in manufactured exports or in fixed asset investment is expected compared to the past. Hence, we expect slower overall growth in industrial production and a shift in the structure of new demand for manufactured products more towards domestic (household) consumption.

3.1.2. Primary energy intensity trends

For past years (1995-2010), primary energy use was divided by the value added (in 2005 constant prices) of each subsector to determine the total primary energy intensity for each subsector. For future years (2015 and 2010), the energy intensity of manufacturing subsectors was calculated using equation 4 and 5 in section 2.1. The results of the energy intensity calculations are shown in Figure 3 and Figure 4.

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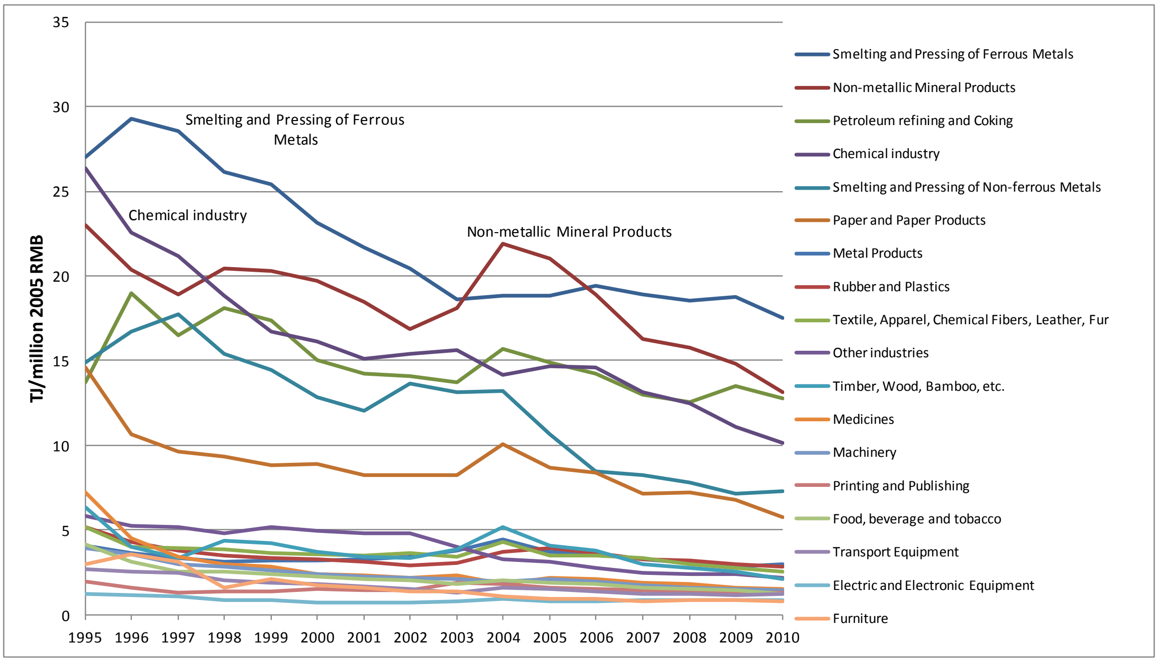
[8] Personal communication, Bob Taylor of Energy Pathways. December 2012.

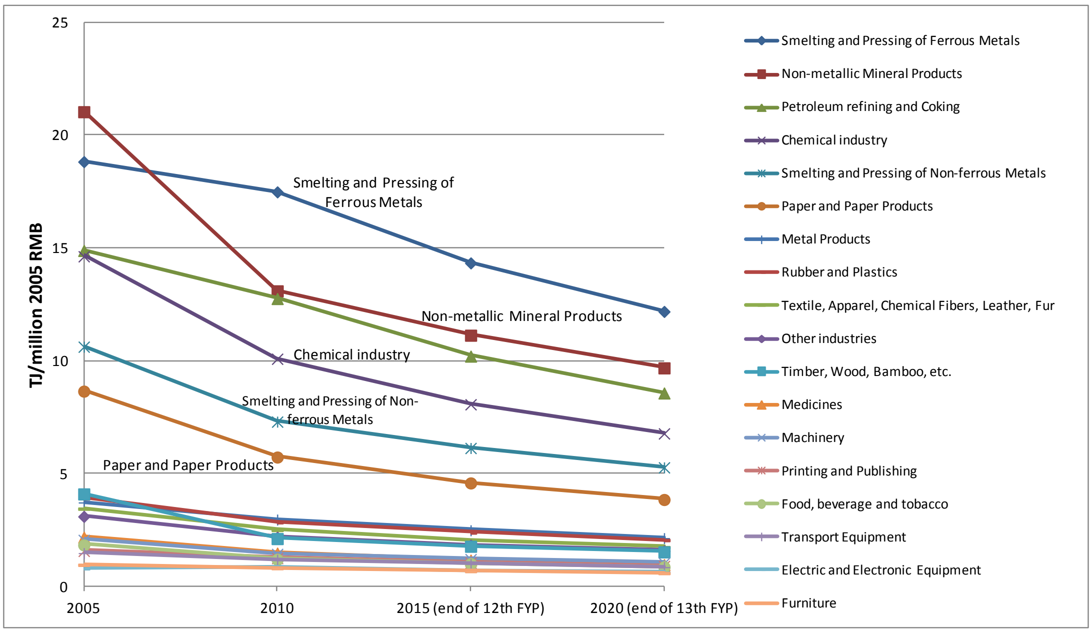
Figure 3 shows that during 1995-2010, smelting and pressing of ferrous metals had the highest primary energy intensity followed (in most years) by nonmetallic minerals and chemical industry. In several years during this period (e.g. 2008-2010), petroleum refining and coking industry overtook chemical industry and had higher energy intensity. The lowest primary energy intensity in 2010 was for manufacturing of furniture and the second-lowest was for electric and electronic equipment manufacturing. Manufacturing of medicines and manufacturing of furniture showed the greatest drop in primary energy intensity from 1995 to 2010, while petroleum refining and coking and manufacturing of metal products showed the lowest drop of primary energy intensity in the same period.

Figure 4 shows the primary energy intensity of manufacturing subsectors in China during 2005-2020. The 2015 and 2020 energy intensities are based on energy intensity reduction rates given in Table 2. Since we assumed steady reduction rates for all manufacturing subsectors by the end of the 12th FYP (2015) and the 13th FYP (2020), we can see that the energy intensity of all subsectors drops during these periods. The reduction rate during the 13th FYP (2016-2020) is lower than that in the 12th FYP (2011-2015). The reduction rates assumed for the 12th FYP are mostly based on Chinese government energy intensity reduction targets for manufacturing subsectors or for industry as a whole. The reduction rates for the 13th FYP are based on expert judgment which is informed by qualitative information on the overall energy intensity reduction target expected for Chinese industry during this period as well as previous targets set in the 11th and 12th FYPs.



Note: calculated based on data from NBS (1996-2011) and NBS (1981-2011)

Figure 3. Primary energy intensity of manufacturing subsectors in China, 1995-2010



Note: Only data from 2005, 2010, 2015, and 2020 are used to plot this graph; thus, the fluctuations in actual energy intensities between 2005 and 2010 are not shown here.

Figure 4. Primary energy[9] intensity of manufacturing subsectors in China, 2005-2020

It can be seen that during 2010-2020, smelting and pressing of ferrous metals, nonmetallic minerals, and chemical industry remain the top three most energy-intensive manufacturing subsectors in China, while their energy intensity has a declining trend in this period.

Overall manufacturing energy intensity drops from 4.9 TJ/million 2005 RMB (167.2 tonne coal equivalent (tce)/million 2005 RMB) in 2010 to 3.9 TJ/million 2005 RMB (133.1 tce/million 2005 RMB) in 2015 (a 20 percent drop compared to the 2010 level) and further declines to 3.2 TJ/million 2005 RMB (109.2 tce/million 2005 RMB) in 2020 (a 17 percent drop compared to the 2015 level). The 20 percent reduction in manufacturing energy intensity in the 12th FYP is in line with the Chinese government target for energy intensity reduction during this period. The government target is to reduce national energy intensity (energy use per GDP) by 16 percent during the 12th FYP. It is expected that the industrial sector will contribute the most to achieving this reduction target because it accounts for around 70 percent of primary energy use in China and significant energy efficiency potential exists in the industrial sector. Thus, the higher rate of energy intensity reduction (20 percent reduction compared to national target of 16 percent reduction) for the overall manufacturing sector in China derived from our bottom-up, sub-sector level calculations is acceptable.

3.1.3. Primary energy use trends

Using the value added and primary energy intensity presented above for each manufacturing subsector, we calculated the primary energy use of each subsector in 2015 and 2020 using equation 1. Since we have three different scenarios for future subsector value added, we have

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[9] In primary energy use reported in NBS (1996-2011), electricity use is converted from final to primary energy using average power generation efficiency in China in various years. The losses in the refining for the production of petroleum products and in coke making for production of coke are not included in the primary energy reported in NBS (1996-2011) .

three primary energy use values calculated under each scenario for the manufacturing subsectors.

In 2010, the total primary energy use of Chinese manufacturing was 53,491 petajoules (PJ) (1,825 Million tonne of coal equivalent (tce)) which is a 36 percent increase from the 2005 level (39,474 PJ or 1,347 Million tce) and a 137 percent increase compared to primary energy use in 1995 (22,551 PJ or 769 Million tce). The increase in primary energy use during the period of 1995-2010 varied among the manufacturing subsectors. The largest percentage increase in primary energy use in 2010 compared to the 1995 level was for electric and electronic equipment manufacturing (388 percent) followed by smelting and pressing of non-ferrous metals (346 percent) and manufacture of metal products (265 percent). The lowest percentage increases in primary energy use in the same period were for manufacture of medicines (18 percent) followed by food, beverage and tobacco (23 percent) and other industries (37 percent). Overall, the primary energy use of all manufacturing subsectors in China increased during this period. Figure 5 shows the trend of primary energy use of different manufacturing subsectors in China during 1995-2010.

Figure 5 shows that the smelting and pressing of ferrous metals, manufacturing of raw chemical materials and chemical products, and non-metallic mineral products manufacturing subsectors are the top three primary energy-consuming manufacturing sectors in China during 1995-2010. Manufacturing of furniture, printing and publishing, and processing of timber, manufacture of wood, bamboo subsectors are the lowest energy-consuming sectors. Figure 6 shows the share of each manufacturing subsector energy use in total primary energy use of the manufacturing in different years.

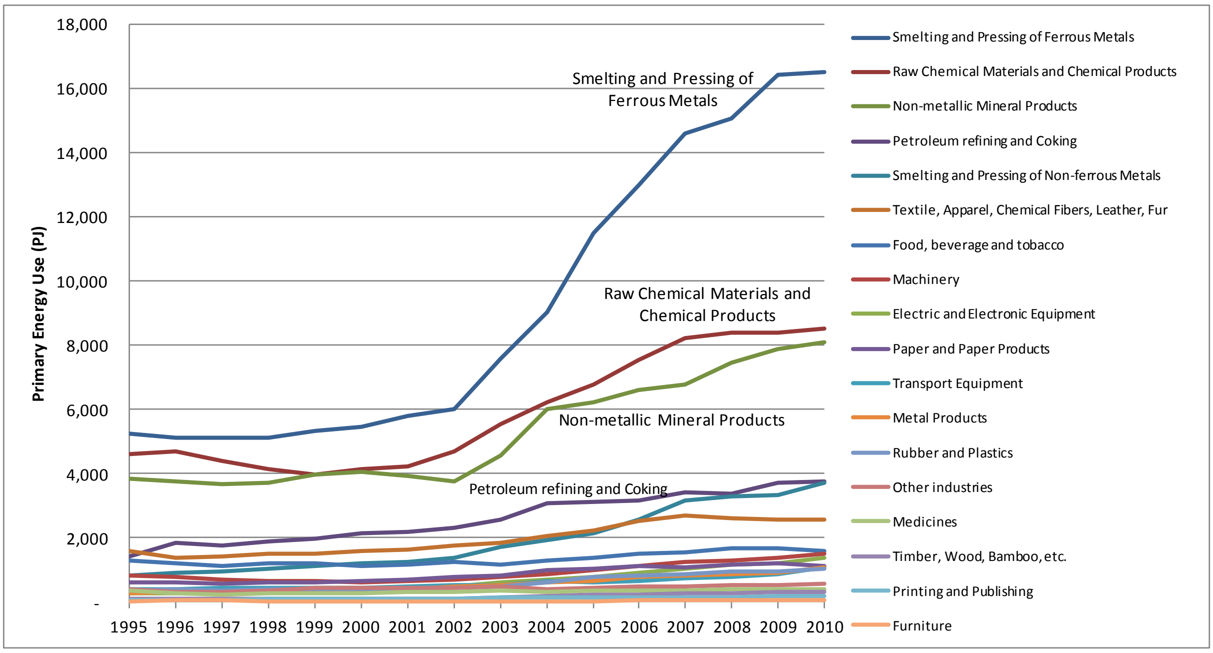

Figure 5. Primary energy[10] use of manufacturing subsectors in China, 1995-2010 (NBS, 1996-2011)

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[10] In primary energy use reported in NBS (1996-2011), electricity use is converted from final to primary energy using average power generation efficiency in China in various years. The losses in the refining for the production of petroleum

Figure 6 shows that under all three scenarios, the share of the smelting and pressing of ferrous metals subsector in total primary energy use of the manufacturing declines; the drop is from 31 percent in 2010 to 27 percent in 2020 under scenario 1 and scenario 2 and to 26 percent under scenario 3. This is because smelting and pressing of ferrous metals is an energy-intensive sector (Figure 3 and Figure 4) and the small reduction in the share of this subsector's value added in total manufacturing value added from 9 percent in 2010 to 6-7 percent in 2020 under different forecast scenarios will significantly influence the primary energy use of this sector.

On the other hand, the share of raw chemical material and chemical product manufacturing in total primary energy use increases from 16 percent in 2010 to 20 percent in 2020 under all three scenarios. This is primarily because of a slight increase in the share of value added of this subsector in total manufacturing value added between 2010 and 2020 (Figure 2). Since raw chemical material and chemical product manufacturing is an energy-intensive sector (Figure 3 and Figure 4), even such a slight increase in the share of value added of this subsector results in a more significant increase in the share of energy use of this sector from total manufacturing primary energy use.

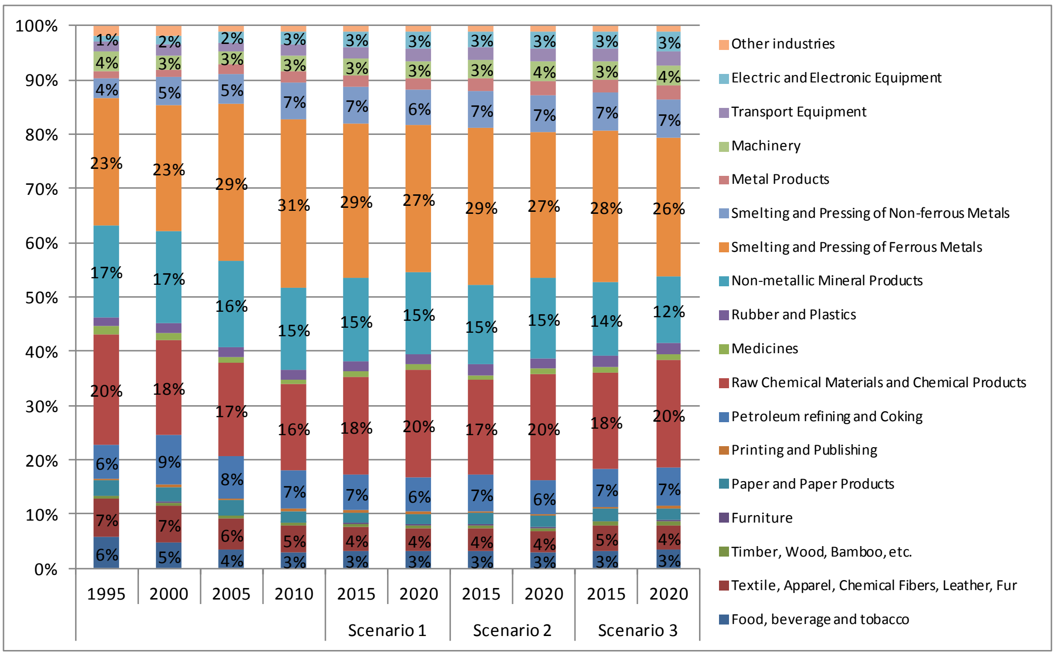

Figure 6. Share of each manufacturing subsector energy use in the total primary energy use of the manufacturing in China, 1995-2010 (NBS, 1996-2011)

The overall value added of Chinese manufacturing increased significantly during 1995-2020 (e.g. by 952 percent under scenario 2), while the overall primary energy use of the manufacturing sector increased by much lower rate in the same period (e.g. by 240 percent under scenario 2). These trends resulted in a decrease in overall manufacturing energy intensity over the period of 1995-2020 (e.g. by 68 percent under scenario 2). Figure 7 shows

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products and in coke making for production of coke are not included in the primary energy reported in NBS (1996-2011) .

the trends in the value added index, primary energy use index, and primary energy intensity index of the manufacturing sector in China.

What effects shaped this decrease in the past and what will likely play an important role in the future? Is it or will it be the result of reduced energy intensity of industries or of increasing shares of low-energy-intensive industries? The retrospective and prospective decomposition analysis described in the following sections helps to answer these questions.

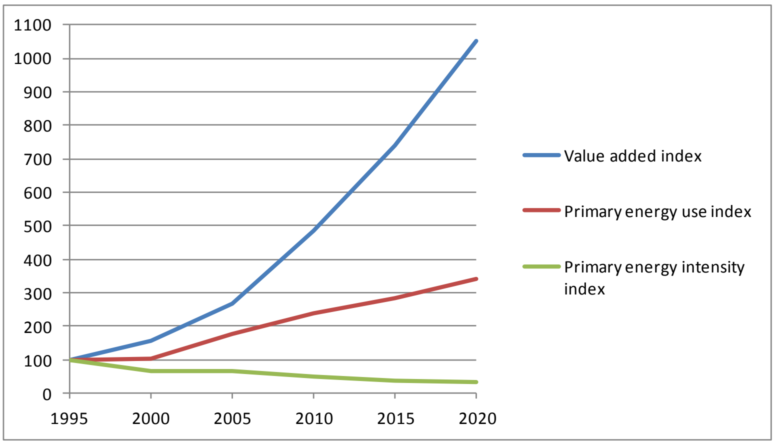

Figure 7. Trends in Chinese manufacturing value added, primary energy use, and primary energy intensity indexes (1995 value = 100) between 1995 and 2020 under scenario 2

3.2. Decomposition of Chinese manufacturing energy use

A LMDI decomposition analysis was performed for the Chinese manufacturing sector for five time periods: 1995-2000, 2000-2005, 2005-2010, 2010-2015, and 2015-2020. These five periods were chosen based on the Chinese government Five Year Plan periods. Each FYP period is associated with a set of Government policies that affect manufacturing energy intensity. Starting in the 11th FYP, specific policies, programs, incentives, and targets were established with the stated intent of reducing China's overall energy intensity and a substantial share of these were focused on reducing manufacturing energy intensity.

It should be noted that the initial year in each period in this decomposition analysis is used as the base year for value added and energy use data. Thus, the decomposition for each period shows the subsequent change compared to the initial year for that period. For example, the decomposition analysis for 1995-2000 shows the changes in primary energy use and influential factors in 1996-2000 (9th FYP) compared to the primary energy use in 1995. Similarly, the decomposition analysis for 2000-2005, 2005-2010, 2010-2015, and 2015-2020 show the changes in primary energy use and influential factors during 10th, 11th, 12th, and 13th FYP, respectively.

As explained in the methodology section, additive non-changing decomposition analysis was used. Since there are three different scenarios for value added forecast data for 2015 and 2020 which subsequently results in three different primary energy use forecasts for manufacturing subsectors for these two years, we conducted the decomposition analysis for each scenario separately. It should be noted that the results of the decomposition analysis of historical data (1995-2010) are the same across all scenarios and only the results of decomposition for future years (2010-2015 and 2015-2020) vary across the three scenarios because of different assumptions used for subsector value added growth rates (see Table 2).

Figures 8-10 show the results of the additive non-changing decomposition analysis of total primary energy use for Chinese manufacturing for the time periods mentioned above under each scenario, separately. During the 11th FYP (2005-2010), the activity effect increased manufacturing energy use by 27,379 PJ (934 million tce, Mtce) due to high value added output from manufacturing. However, the structural effect slightly reduced manufacturing primary energy use in this period by 1,081 PJ (37 Mtce). After the intensity effect, which also reduced primary energy use by 12,281 PJ (419 Mtce), is taken into account, the total change in Chinese manufacturing primary energy use during 11th FYP was equal to an increase of 14,017 PJ (478 Mtce).

Figures 8-10 show that under all three scenarios, except in the period of 2000-2005 (10th FYP), the activity and intensity effects were the two dominant influences working against each other to drive energy use upward (activity effect) or downward (intensity effect). In the period 2000-2005, the intensity effect had a much smaller impact compared to all other periods studied. Also, 2000-2005 is the only period when the structural effect is positive, driving manufacturing energy use upwards. During all other periods the structural effect was negative and helped to reduce manufacturing energy use even though its impact was rather small compared to other effects. The primary reason why the structural effect was positive in 2000-2005 (10th FYP) is that the share of value added from smelting and pressing of ferrous metals in total manufacturing value added increased from 7 percent in 2000 to 10 percent in 2005. Since this sector has the highest energy intensity among all other sectors, such a seemingly small change in its share of value added in total manufacturing value added can significantly impact the structural effect in the decomposition analysis. The same issue is applicable to raw chemical materials and chemical products manufacturing which is one of the top three energy-intensive industries in China; a slight increase in its share from total manufacturing value added (from 7 percent in 2000 to 8 percent in 2005) can result in a positive increase in the structural effect. However, this might partly be compensated by the non-metallic mineral products sector which is also a top energy-intensive sector, yet its share of total manufacturing value added dropped slightly from 6 percent in 2000 to 5 percent in 2005.

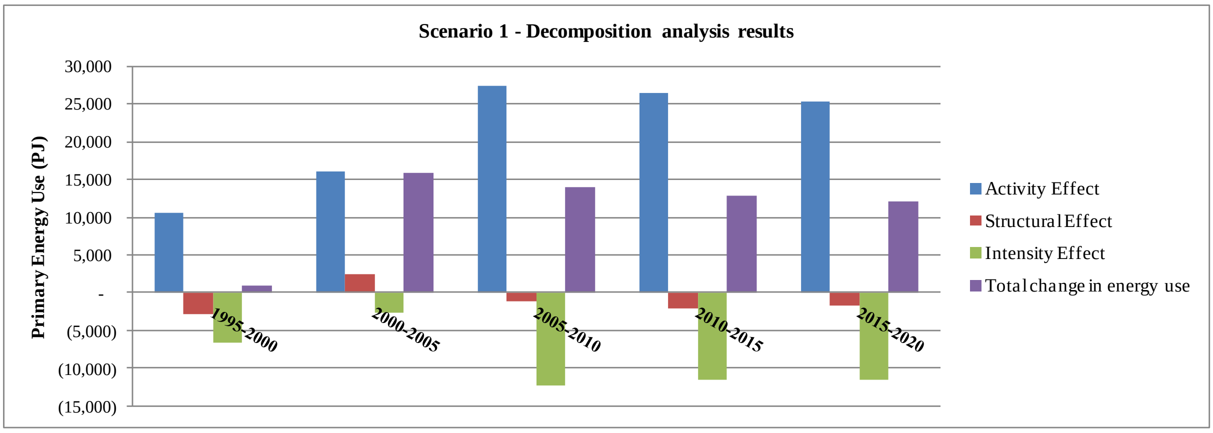

Figure 8. Scenario 1: Results of retrospective and prospective decomposition of primary energy[11] use of Chinese manufacturing during the 9th, 10th, 11th, 12th, and 13th Five Year Plans

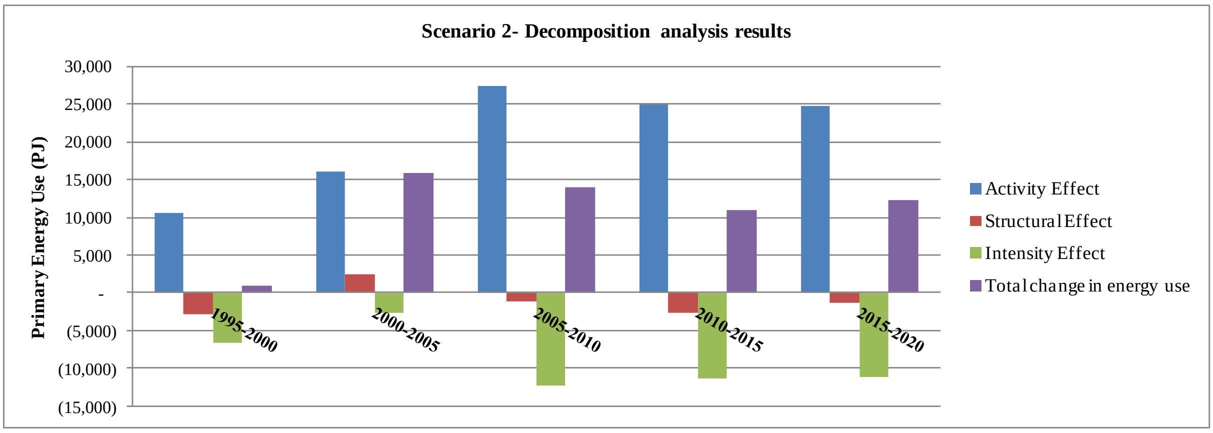

Figure 9. Scenario 2: Results of retrospective and prospective decomposition of primary energy use of Chinese manufacturing during the 9th, 10th, 11th, 12th, and 13th Five Year Plans

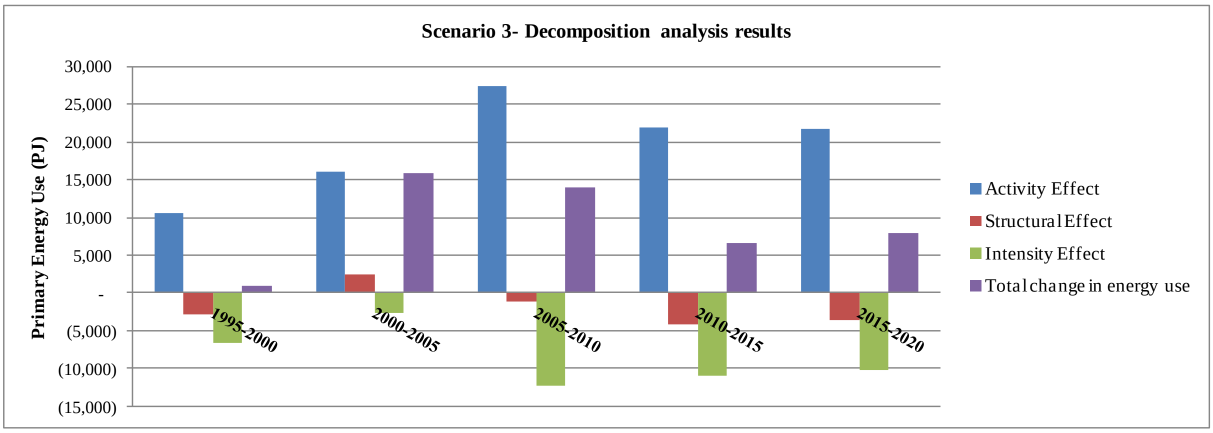

Figure 10. Scenario 3: Results of retrospective and prospective decomposition of primary energy use of Chinese manufacturing during the 9th, 10th, 11th, 12th, and 13th Five Year Plans

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[11] In primary energy use reported in NBS (1996-2011), electricity use is converted from final to primary energy using average power generation efficiency in China in various years. The losses in refining of petroleum products and in production of coke are not included in the primary energy reported in NBS (1996-2011) .

The intensity effect during the 10th FYP (2000-2005) is the smallest compared to the other periods because of a very small decline in overall manufacturing energy intensity during this period. This was primarily because the energy intensity of some manufacturing subsectors, especially the top five energy-intensive manufacturing subsectors (except smelting and pressing of ferrous metals), either remained relatively steady or even increased in some cases (Figure 3). For example, primary energy use of the non-metallic mineral product sector increased by 55 percent during 2000-2005, while its value added only increased by 45 percent in the same period. This resulted in increased primary energy intensity for this sector in this period. Such an increase in energy intensity in several manufacturing subsectors was due to the sudden boom in production capacity and construction of manufacturing plants and the rapid increase in production without enough attention to energy efficiency. Later in the 10th FYP period and especially during the 11th FYP, in an attempt to control the energy intensity of manufacturing, the Chinese government implemented series of policies and programs to reduce the energy intensity of manufacturing sectors, especially the energy-intensive industries. Programs like the “Top-1000 Enterprises Energy Saving Program” and the “10 Key Energy Saving Projects Program” implemented during the 11th FYP substantially helped to control the energy intensity of the manufacturing (Price et al. 2011).

For the 12th FYP and 13th FYP, the results of the decomposition analyses show a similar pattern across the scenarios but with different magnitudes for various effects. The differences between the three scenarios and the primary reasons for such differences can be summarized as:

- In the 12th FYP and 13th FYP, the activity effect is largest in scenario 1 and smallest in scenario 3. This is directly because of the higher value added AAGRs assumed in scenario 1, which are mostly based on Chinese reported data, and the lower value added AAGRs assumed in scenario 3, which are mostly based on expert judgment informed by various sources of information and taking into account China’s overall GDP growth rate and the expected share of industry from China’s overall GDP in 2015 and 2020.
- In the 12th FYP and 13th FYP, contrary to the activity effect, the structural effect is largest (in negative value) in scenario 3. This is primarily because of the fact that the share of value added of smelting and pressing of ferrous metals and non-metallic mineral products sector, which were the two top energy-intensive sectors, in total manufacturing value added in 2015 and 2020 declined the most in scenario 3 when compared to the 2010 shares. In other words, the share of these two sectors in total manufacturing value added in 2015 and 2020 is lower in scenario 3 compared to scenarios 1 and 2 (see Figure 2). This is the result of our assumptions on value added AAGRs for different subsectors (Table 2). In scenario 3, we assumed a further shift from energy-intensive industries to non-energy intensive industries by assuming lower value added AAGRs for the energy-intensive sectors and higher value added AAGRs for the less energy-intensive sectors. This is necessary if China wants to adjust the structure of its manufacturing and move towards less energy-intensive and lower polluting manufacturing.

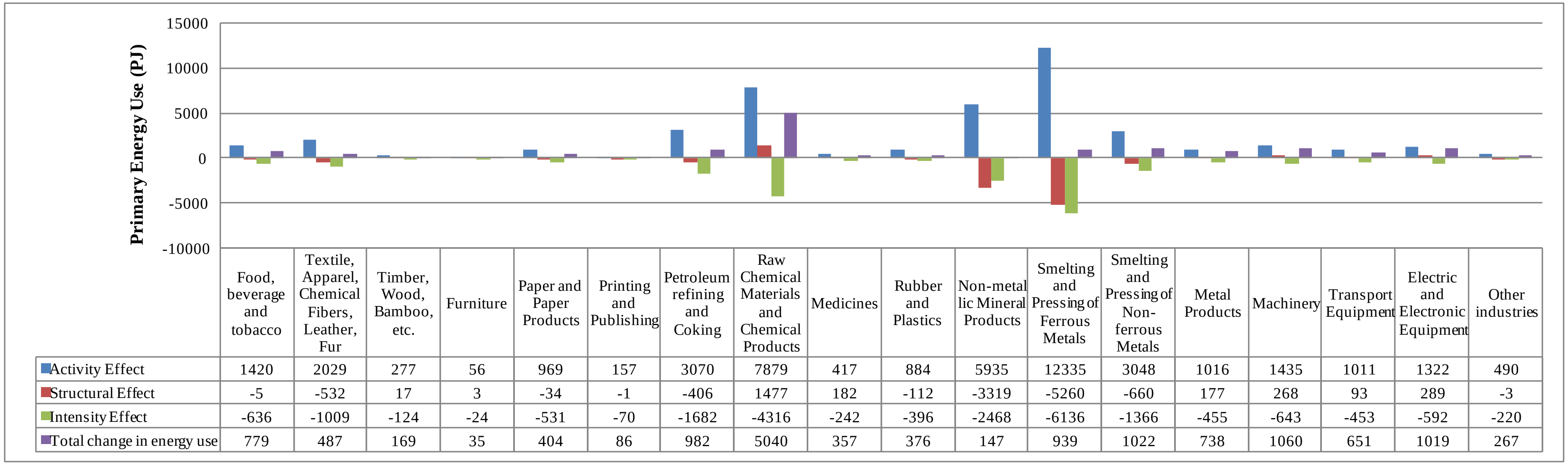
- In the 12th FYP and 13th FYP, the intensity effect is almost in the same range across all three scenarios, with scenario 1 having slightly greater (in negative value) energy intensity effect. This is mainly because we assumed a similar energy intensity reduction rate during the 12th FYP and 13th FYP for all three scenarios (Table 2). The slight differences between intensity effects across scenarios comes from the differences in absolute energy use in manufacturing subsectors in 2015 and 2020 under each scenario which is the result of different value added AAGR assumptions. As can be seen in equation 9, absolute energy use of a manufacturing subsector plays a role in the calculation of the intensity effect in addition to the energy intensity of the subsectors. Nonetheless, the intensity effect plays a significant role in reducing primary energy use during the 12th FYP and 13th FYP. This is primarily because of aggressive policies by the Chinese government to reduce the energy use per value added of the manufacturing sector. The "Top-1000 Enterprises Energy Saving Program" and the "10 Key Energy Saving Projects Program" implemented during the 11th FYP have both been extended to the 12th FYP with the Top 1000 program expanding to the "Top-10,000 Enterprises Energy Saving Program". These programs along with other policies and incentives are helping to reduce the energy intensity of the manufacturing in China; hence we see a strong intensity effect in the decomposition analysis.

Breaking down the decomposition analysis results by industrial subsectors shows the contribution of each subsector to the overall results. Figure 11 shows the results of the analysis for scenario 3 for the period of 2010-2020 for the decomposition analysis by subsector. Similar results for scenario 1 and scenario 2 are presented in Appendix 1.

In the scenario 3, both the activity effect and the intensity effect are positive for all subsectors during the 2010 to 2020 period. The structural effect varies by subsectors, with most showing a negative trend while a few show a positive trend, indicating that structural change within subsectors is highly variable.

The main positive increases in the structural effect were for raw chemical materials and chemical products manufacturing, electric and electronic equipment manufacturing, and the machinery industry. This implies that the share of these three industries in total manufacturing value added increased from 2010 to 2020. The largest negative values in the structural effect come from non-metallic mineral products, smelting and pressing of ferrous metals, smelting and pressing of non-ferrous metals, petroleum refining and coking, and the textile industry. This means the share of these industries in total manufacturing value added decreased from 2010 to 2020.

All manufacturing subsectors have negative intensity effects. This confirms that the primary energy intensity of all subsectors is projected to decrease in the year 2020 compared to energy intensities in 2010.



	Food, beverage and tobacco	Textile, Apparel, Chemical Fibers, Leather, Fur	Timber, Wood, Bamboo, etc.	Furniture	Paper and Paper Products	Printing and Publishing	Petroleum refining and Coking	Raw Chemical Materials and Chemical Products	Medicines	Rubber and Plastics	Non-metallic Mineral Products	Smelting and Pressing of Ferrous Metals	Smelting and Pressing of Non-ferrous Metals	Metal Products	Machinery	Transport Equipment	Electric and Electronic Equipment	Other industries
🟦Activity Effect	1420	2029	277	56	969	157	3070	7879	417	884	5935	12335	3048	1016	1435	1011	1322	490
🟥Structural Effect	-5	-532	17	3	-34	-1	-406	1477	182	-112	-3319	-5260	-660	177	268	93	289	-3
🟩Intensity Effect	-636	-1009	-124	-24	-531	-70	-1682	-4316	-242	-396	-2468	-6136	-1366	-455	-643	-453	-592	-220
🟪Total change in energy use	779	487	169	35	404	86	982	5040	357	376	147	939	1022	738	1060	651	1019	267

Figure 11. Scenario **3**: Results of additive non-changing decomposition of primary energy use of Chinese manufacturing by subsectors, 2010-2020

There are number of limitations and sources of uncertainty in this study and most other studies that try to forecast the future value added for manufacturing subsectors as well as their future energy intensities. For example, the projected value added AAGRs as well as the energy intensity reduction rates between 2010 and 2020 given in Table 2 are a source of uncertainty. Even so, the scenario development and decomposition analysis in this study can help to understand how changes in value added AAGRs can affect overall energy consumption in the future. Therefore, the result of such studies should be reviewed and interpreted with caution keeping in mind the limitations and uncertainties.

4. Conclusions

In this study, a bottom-up analysis of the energy use of Chinese manufacturing is performed using data at the subsector level. Both retrospective and prospective analyses are conducted in order to assess the impact of factors that influence the energy use of the manufacturing sector in the past (1995-2010) and estimate the likely impact in the future (2010-2020).

The analysis results show that top energy-consuming subsectors such as smelting and pressing of ferrous metals, raw chemical materials and chemical products manufacturing, and non-metallic mineral product manufacturing use more energy per value added, and, although they account for a large share of Chinese manufacturing primary energy use (62 percent in 2010), they together produced only 22 percent of total Chinese manufacturing value added in 2010. In contrast, the electric and electronic equipment manufacturing, food, beverage and tobacco industry, and machinery manufacturing accounted for 36 percent of Chinese manufacturing value added while just consuming 8 percent of the total Chinese manufacturing primary energy use in 2010.

The retrospective decomposition analysis described in this report shows that energy intensity reduction was not the only reason for reduced energy use in Chinese manufacturing between 1995 and 2010. Structural effects played an important role in reducing energy demand between 1995 and 2000 and a minor role between 2005 and 2010. However, during 2000-2005 the structural effect was positive and drove manufacturing energy use upward primarily because the share of value added from top energy-intensive sectors like smelting and pressing of ferrous metals and raw chemical materials and chemical products manufacturing in total manufacturing value added increased during this period.

The three scenarios produced for the forward looking (prospective) decomposition analysis for 2010-2020 show a similar pattern for different effects with only varying magnitudes for each effect across the scenarios. The activity effect is largest under scenario 1 because higher value added AAGRs are assumed for the manufacturing subsectors under this scenario. The structural effect, however, is largest in scenario 3 because the share of value added of energy-intensive subsectors such as smelting and pressing of ferrous metals and non-metallic mineral products sectors in total manufacturing value added in 2015 and 2020 is lower in scenario 3 compared to other two scenarios.

The scenario analysis indicates that if China wants to shift from energy-intensive and polluting industries to less energy-intensive industries, the value added AAGRs in 2015 and 2020 should be more in line with scenario 3. The assumed value added AAGRs for scenario 3 are informed by possible growth rates that are foreseen for each subsector. Such structural change is also a result of shifts in demand for manufactured products. The government can influence demand for manufactured products indirectly, but only to some extent, and generally only temporarily. For example, the government can spur immediate demands for manufactured products for infrastructure projects by creating a large stimulus package of public sector infrastructure projects. But, in the end, this is limited and only temporary, as the government funding is limited. More importantly, the needs of the economy for infrastructure at a given time are also limited. If investments in infrastructure begin to get increasingly out of balance with what the economy needs, investments become increasingly wasteful and uneconomic. Hence, in addition to government policies in the past, the industrial structural change in China we have analyzed in this study are also caused by broad macroeconomic trends such as where a country is on the development path, emerging demand trends, and the country's economic comparative advantage in meeting different types of demand.

The results of our analysis also show that the intensity effect always reduces primary energy use during the study period. This could be for various reasons including aggressive policies and programs to reduce energy intensity, fiscal incentives given by the Chinese government for energy efficiency projects (e.g. the 10 Key Energy Saving Projects Program), modernization of the industry and phasing out of the inefficient, backward technologies, increased energy prices, etc. These reasons along with other influential factors have continued pressuring industries to improve energy efficiency to comply with regulations and to reduce costs. This is likely to continue up to 2020 and perhaps beyond. It should also be noted that the intensity effect in the decomposition analysis includes two components: 1. changes in the physical energy use per unit of production and 2. changes in the structure within each subsector to lower energy intensive or high value added production. For example, the food and beverage subsector has many further subsectors that produce various products with different energy intensities. Each of the manufacturing subsectors shown in Table 1 have several different subsectors and production processes that produce different types of products with various energy intensities. Structural change within subsectors can have a large effect on subsector energy use per value added. However, because of a lack of further disaggregated energy use and value added data, we are unable to quantify intra-subsector structural change.

More research is needed to determine the best indicators of energy use for each manufacturing subsector. Energy intensities expressed in terms of physical or monetary output can produce different results. For complex and heterogeneous industries, more disaggregate data may be required to develop meaningful indicators of energy efficiency.

There is no direct way of measuring energy savings. Hence, one must rely on a series of indicators to infer changes in energy use. Many countries have developed indices of energy efficiency performance for monitoring purposes, and, increasingly, as a basis for policy making. Theses indices are based on energy intensity effects calculated at a disaggregated level but summarize results at more aggregate levels. The purpose of these indices is to provide a quick assessment tool for policy makers based on meaningful analysis. This study's research on decomposition analysis can serve as the starting point in developing similar indices for China. Ultimately, this index could be used as a performance index to measure progress in overall energy efficiency in China.

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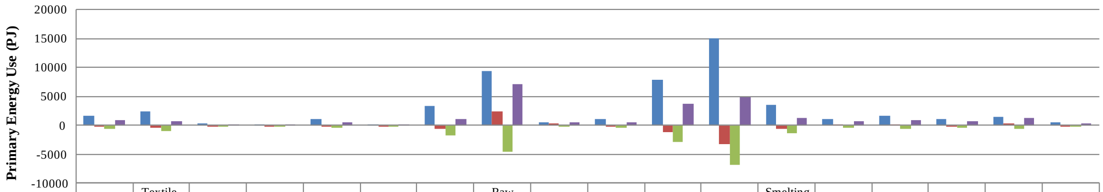
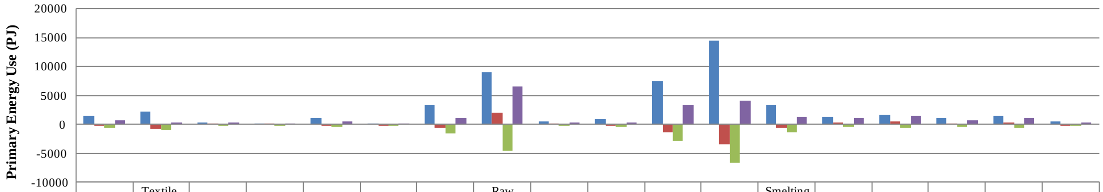
Appendixes

A.1. Decomposition of primary energy use of Chinese manufacturing by subsectors during 2010-2020



	Food, beverage and tobacco	Textile, Apparel, Chemical Fibers, Leather, Fur	Timber, Wood, Bamboo, etc.	Furniture	Paper and Paper Products	Printing and Publishing	Petroleum refining and Coking	Raw Chemical Materials and Chemical Products	Medicines	Rubber and Plastics	Non-metallic Mineral Products	Smelting and Pressing of Ferrous Metals	Smelting and Pressing of Non-ferrous Metals	Metal Products	Machinery	Transport Equipment	Electric and Electronic Equipment	Other industries
🟦Activity Effect	1593	2303	303	61	1065	176	3400	9284	491	990	7808	14950	3445	1100	1531	1106	1502	537
🟥Structural Effect	-50	-546	-10	-3	-114	-5	-609	2377	236	-147	-1160	-3371	-714	54	40	-3	300	-48
🟩Intensity Effect	-652	-1047	-124	-24	-533	-72	-1702	-4647	-261	-405	-2967	-6795	-1410	-451	-627	-453	-615	-220
🟪Total change in energy use	891	711	169	34	418	99	1090	7015	466	438	3680	4784	1321	704	944	650	1187	269

Figure A.1. Scenario **1**: Results of additive non-changing decomposition of primary energy[1] use of Chinese manufacturing by subsectors during 2010-2020



	Food, beverage and tobacco	Textile, Apparel, Chemical Fibers, Leather, Fur	Timber, Wood, Bamboo, etc.	Furniture	Paper and Paper Products	Printing and Publishing	Petroleum refining and Coking	Raw Chemical Materials and Chemical Products	Medicines	Rubber and Plastics	Non-metallic Mineral Products	Smelting and Pressing of Ferrous Metals	Smelting and Pressing of Non-ferrous Metals	Metal Products	Machinery	Transport Equipment	Electric and Electronic Equipment	Other industries
🟦Activity Effect	1483	2124	309	61	1056	168	3300	8900	453	947	7497	14401	3370	1179	1628	1082	1434	526
🟥Structural Effect	-196	-783	27	1	-60	-12	-600	2084	171	-175	-1324	-3575	-644	335	395	21	239	-35
🟩Intensity Effect	-620	-986	-129	-25	-540	-70	-1687	-4551	-246	-396	-2911	-6687	-1410	-493	-681	-453	-600	-220
🟪Total change in energy use	666	355	207	37	456	86	1012	6433	378	376	3263	4139	1316	1021	1342	651	1074	270

Figure A.2. Scenario **2**: Results of additive non-changing decomposition of primary energy use of Chinese manufacturing by subsectors during 2010-2020

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[1] In primary energy use reported in NBS (1996-2011), electricity use is converted from final to primary energy using average power generation efficiency in China in various years. The losses in the refining for the production of petroleum products and in coke making for production of coke are not included in the primary energy reported in NBS (1996-2011) .