LBNL-4600E

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Inventory of China's Energy-Related CO_2 Emissions in 2008

David Fridley, Nina Zheng, Yining Qin
China Energy Group, Energy Analysis Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

March 2011

This work was supported by the Energy Information Administration of the US Department of Energy through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Disclaimer

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

Ernest Orlando Lawrence Berkeley National Laboratory is an equal opportunity employer.

Executive Summary

Although China became the world's largest emitter of energy-related CO_2 emissions in 2007, China does not publish annual estimates of CO_2 emissions and most published estimates of China's emissions have been done by other international organizations. Undertaken at the request of the Energy Information Administration (EIA) of the US Department of Energy, this study examines the feasibility of applying the EIA emissions inventory methodology to estimate China's emissions from published Chinese data. Besides serving as a proof of concept, this study also helps develop a consistent and transparent method for estimating China's CO_2 emissions using an Excel model and identified China-specific data issues and areas for improvement.

This study takes a core set of data from the energy balances published in the *China Energy Statistical Yearbook 2009* and *China Petrochemical Corporation Yearbook 2009* and applies the EIA's eight-step methodology to estimate China's 2008 CO_2 emissions. First, China's primary and secondary fuel types and consumption by end use are determined with slight discrepancies identified between the two data sources and inconsistencies in product categorization with the EIA. Second, energy consumption data are adjusted to eliminate double counting in the four potential areas identified by EIA; consumption data from China's Special Administrative Regions are not included. Physical fuel units are then converted to energy equivalents using China's standard energy measure of coal equivalent (1 kilogram = 29.27 MJ) and IPCC carbon emissions coefficients are used to calculate each fuel's carbon content. Next, carbon sequestration is estimated following EIA conventions for other petroleum products and non-energy use of secondary fuels. Emissions from international bunker fuels are also subtracted under the "reference" calculation of estimating apparent energy consumption by fuel type and the "sectoral" calculation of summing emissions across end-use sectors. Adjustments for the China-specific conventions of reporting foreign bunkers and domestic bunkers fueling abroad are made following IPCC definitions of international bunkers and EIA reporting conventions, while the sequestration of carbon in carbon steel is included as an additional adjustment. Under the sectoral approach, fuel consumption of bunkers and other transformation losses as well as gasoline consumption are reallocated to conform to EIA sectoral reporting conventions.

To the extent possible, this study relies on official energy data from primary sources. A limited number of secondary sources were consulted to provide insight into the nature of consumption of some products and to guide the analysis of carbon sequestered in steel. Beyond these, however, the study avoided trying to estimate figures where directly unavailable, such as natural gas flaring. As a result, the basic calculations should be repeatable for other years with the core set of data from National Bureau of Statistics and Sinopec (or a similarly authoritative source of oil product data).

This study estimates China's total energy-related CO_2 emissions in 2008 to be 6666 Mt CO_2, including 234.6 Mt of non-fuel CO_2 emissions and 154 Mt of sequestered CO_2. Bunker fuel emissions in 2008 totaled 15.9 Mt CO_2, but this figure is underestimated because fuel use by Chinese ship and planes for international transportation and military bunkers are not included. Of emissions related to energy consumption, 82% is from coal consumption, 15% from petroleum and 3% from natural gas. From the

sectoral approach, industry had the largest share of China's energy-related CO_2 emissions with 72%, followed by residential at 11%, transport and telecommunications at 8%, and the other four (commerce, agriculture, construction and other public) sectors having a combined share of 9%. Thermal electricity and (purchased) heat (to a lesser degree) are major sources of fuel consumption behind sectoral emissions, responsible for 2533 Mt CO_2 and 321 Mt CO_2, respectively.

The 2008 emissions estimated for China in this study falls within the range of other international estimates, and suggests that the EIA methodology can be adopted to estimate China's emissions if the proper adjustments are made. While these results are helpful in understanding China's annual emissions, several key areas of data challenges affect the accuracy of this estimate. Industrial process-based emissions – an important source of emissions given China's industry-intensive economy and size of its cement sector – have not been included in this calculation and could be the focus of further model refinement. The accuracy of the Chinese emissions estimate can be further improved by addressing two unreported international bunker categories and developing China-specific carbon sequestration coefficients for non-fuel use energy products.

Contents

Executive Summary i

List of Tables v

List of Figures vi

1. Introduction 1

2. Methodology 2

2.1 Determine fuel consumption by fuel type and end use 2

2.2 Adjust energy consumption data to eliminate double counting 4

2.3 Determine energy consumption data to account for fuel consumption in territories 5

2.4 Convert physical fuel units to energy equivalents 5

2.5 Identify carbon emission coefficients and calculate total carbon content of each fuel type 7

2.6 Determine value of carbon sequestered in products 8

2.7 Subtract carbon in international bunker fuels 9

2.8 Calculate and sum emissions for all fuel types and end uses 9

2.9 Variances, Adjustments, Missing Data, and Incomplete Data 10

Primary Energy Calculation 10

Bunker Adjustments 10

Carbon Steel Adjustments 12

Sectoral Approach Adjustments 13

Incomplete Data and Emission Sources Excluded 13

3. Results 14

3.1 Total Emissions 14

3.2 Sectoral Emissions 17

Agriculture 17

Industry 18

Construction 19

Transport, Post and Telecommunications 21

Commerce 22

Residential 23

Other (Public) Sector 24

Thermal Electricity 26

Heat 27

3.3 Emissions from Non-fuel Use of Energy 28

3.4 Carbon Sequestration 31
4. Conclusions and Areas for Improvement 34
References 35
Appendix: Overview of the China Carbon Emissions Model 37
Structure of the China Carbon Emissions Model 37
Model Data Inputs 38
Model Calculations 42

List of Tables

Table 1. China Energy-Related CO_2 Emissions Estimates 1
Table 2. China Primary and Secondary Fuel Types 2
Table 3. Other Petroleum Products 3
Table 4. Comparison of Sinopec and NBS data on Other Petroleum Products 4
Table 5. China Energy End-Use Sectors 4
Table 6. NBS Standard Conversion Factors 6
Table 7. Carbon Coefficients 7
Table 8. Sequestration Coefficients for Non-Energy Use Fuels and Non-Fuel Energy Products 8
Table 9. China's 2008 Total CO_2 Emissions from Energy Consumption: Reference Approach 14
Table 10. China's 2008 Total CO_2 Emissions from Energy: Sectoral Approach 16
Table 11. China's 2008 CO_2 Emissions from Energy: Agriculture 17
Table 12: China's 2008 CO_2 Emissions from Energy: Industry 18
Table 13. China's 2008 CO_2 Emissions from Energy: Construction 20
Table 14. China's 2008 CO_2 Emissions from Energy: Transport, Post and Telecommunications 21
Table 15. China's 2008 CO_2 Emissions from Energy: Commerce 22
Table 16. China's 2008 CO_2 Emissions from Energy: Residential 23
Table 17. China's 2008 CO_2 Emissions from Energy: Other (Public) Sector 25
Table 18. China's 2008 CO_2 Emissions from Energy: Thermal Electricity Generation 26
Table 19. China's 2008 CO_2 Emissions from Energy: Heat Production 27
Table 20. China's 2008 CO_2 Emissions from Nonfuel Use of Energy Fuels 28
Table 21. China's 2008 Carbon Sequestration by Nonfuel Use of Energy Fuels 31

List of Figures

Figure 1. China's 2008 Total CO_2 Emissions from Energy Consumption by Fuel 15
Figure 2. China's 2008 Total CO_2 Emissions from Energy by Sector 16
Figure 3. China's 2008 Agriculture CO_2 Emissions by Major Fuels..... 18
Figure 4. China's 2008 Industry CO_2 Emissions by Major Fuels 19
Figure 5. China's 2008 Construction Sector CO_2 Emissions by Major Fuels 20
Figure 6. China's 2008 Transport, Post and Telecommunications Sector CO_2 Emissions by Major Fuels .. 22
Figure 7. China's 2008 Commerce Sector CO_2 Emissions by Major Fuels..... 23
Figure 8. China's 2008 Residential Sector CO_2 Emissions by Major Fuels 24
Figure 9. China's 2008 Other (Public) Sector CO_2 Emissions by Major Fuels..... 25
Figure 10. China's 2008 Thermal Electricity Sector CO_2 Emissions by Major Fuels 27
Figure 11. China's 2008 Heat Sector CO_2 Emissions by Major Fuels..... 28
Figure 12. China's 2008 CO_2 Emissions from Non-fuel Use of Energy by Fuel Type 30
Figure 13. China 2008 CO_2 Sequestration by Nonfuel Uses of Energy Fuels by Fuel Type 33

1. Introduction

In 2007, China became the world's largest emitter of energy-related CO_2. This milestone was not reported by China, because China does not publish annual estimates of its CO_2 emissions. Estimates of China's emissions have been variously published by the Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory, the Energy Information Administration (EIA) of the US Department of Energy, the International Energy Agency (IEA), and the Netherlands Environmental Assessment Agency (PBL), among others. Although all the published estimates ultimately rely on energy data reported by China's National Bureau of Statistics (NBS), differences in methodology and assumptions have resulted in variation in the published figures. In recent years, the estimates from CDIAC have ranged lowest, while those from PBL and EIA tend to be the highest (Table 1).

Table 1. China Energy-Related CO_2 Emissions Estimates

Estimate Source	2007	2008	2009
CDIAC	5,863	6,262	6,815
EIA	6,257	6,800	7,707
PBL*	6,415	6,826	7,420
IEA (Reference)	6,044	6,558	n/a
This Study (Reference)	-	6,666	-

*Excluding cement production process emissions

Since the Energy Act of 1992 directed the EIA to prepare inventories of US national emissions of greenhouse gases, EIA has annually published its calculation of US national emissions of all greenhouse gases. The methodology underlying these calculations has been fully described in the EIA publication *Documentation for Emissions of Greenhouse Gases in the United States 2006* (EIA 2008). With respect to carbon dioxide emissions from fossil fuel energy combustion, EIA "follows a bottom-up approach using consumption data disaggregated by fuel type and sector, as recommended by the *Good Practice Guidance* of the Intergovernmental Panel on Climate Change (IPCC)." The approach lays out both the estimation process and the data required in the estimation in a transparent and consistent manner.

Given China's lack of published emissions estimates, EIA requested LBNL to look in detail at the feasibility of applying the EIA inventory methodology to the estimation of emissions from fossil-fuel combustion in China using China's published energy data. The goals of the study are several-fold: to develop a CO_2 emissions estimate on the same basis as the US figure; to identify differences and problems with the data scope; and to identify calculations that cannot be done owing to a lack of publicly available data. The core set of data for this study is the energy balances published in the *China Energy Statistical Yearbook 2009* (NBS, 2010a) (hereafter, CESY 2009) containing the latest revisions of China's energy production and consumption figures from 1996 to 2008; this study, however, examines only the last year, 2008, for proof of concept of application of this approach.

The results of this study include both this report providing details about the calculation methodology and results, as well as an Excel model in which the calculations were done. The Excel model can be populated with the same data sources for other years to provide CO_2 emissions estimates on the same

basis as the 2008 estimate under study here. Screenshots and further details on the structure and use of the model are provided in the Appendix.

2. Methodology

The EIA *Documentation* lays out an eight-step estimation methodology:

1. Determine fuel consumption by fuel type and end use
2. Adjust energy consumption data to eliminate double counting
3. Determine energy consumption data to account for fuel consumption in territories
4. Convert physical fuel units to energy equivalents
5. Identify carbon emission coefficients and calculate total carbon content of each fuel type
6. Determine value of carbon sequestered in products
7. Subtract carbon in international bunker fuels
8. Calculate and sum emissions for all fuel types and end uses

Each of these steps will be examined in detail below.

2.1 Determine fuel consumption by fuel type and end use

The fuel types considered in this study follow the categories defined and reported in the CESY 2009. These are shown in Table 2.

Table 2. China Primary and Secondary Fuel Types

	Coal and Coal-derived	**Petroleum**	**Natural Gas**
Primary	Raw Coal	Crude Oil	Natural Gas
Secondary	Cleaned Coal	Gasoline	
	Other Washed Coal	Kerosene	
	Briquettes	Diesel Oil	
	Coke	Fuel Oil	
	Coke Oven Gas	LPG	
	Other Gas	Refinery Gas	
	Other Coking Products	Other Petroleum Products	

"Other Petroleum Products" primarily constitutes non-energy feedstocks and non-fuel products that are not further broken down by type in the NBS data. Because these products are the primary source of sequestered carbon in the emissions calculation (see 2.6), an alternative source of data was found to provide details on composition of this group of products. In this study, data were sourced from the *China Petrochemical Corporation Yearbook 2009*, which provides national data on the production, import, and export of the following Other Petroleum Products, shown in Table 3 along with the EIA categories (Sinopec 2009).

Table 3. Other Petroleum Products

China Product Category	EIA Product Category
Petroleum Asphalt	Asphalt and Road Oil
Lubricants	Lubricants
Lubricant base oil	Lubricants
n/a	Miscellaneous Petroleum Products
n/a	Pentanes Plus
Petroleum Coke	Petroleum Coke
Naphtha	Petrochemical Feedstock
Paraffin	Waxes and Polishes
Solvent oil	Special Naphtha
Detergents	n/a
Chemical light oil	Petrochemical Feedstock

Source: Sinopec 2009; EIA 2008

Generally, China's product categories map directly to those tracked by the EIA and used in their emissions calculations. However, two categories of China's products—chemical light oil and naphtha—map to a single EIA product—petrochemical feedstock. In China, "naphtha" is reported solely on an international trade basis, corresponding to the commodity classification meeting specific quality requirements as used in international trade. Domestic production of naphtha used in domestic petrochemical facilities is classified as part of "chemical light oil" (化工轻油 huagong qingyou), a category name in use since at least the 1970s that refers to a number of different product streams all used in the petrochemical industry, primarily in ethylene production. In the 1980s, gasoil was the major constituent of chemical light oil, but since the modernization and expansion of the ethylene industry began in earnest in the 1990s, the major constituent is now naphtha supplemented with hydrocracker tail oil (Zhang 2010). Although chemical light oil also includes other streams including feedstocks in the light gasoil distillation range for the production of white oils (mineral oils), and "flax softening oil" for softening flax fibers for bag production, in terms of the emissions calculations, the entire product category is treated in this study as naphtha owing to the lack of detailed composition data.

Because these data are derived from a secondary source outside of NBS, there exists a small discrepancy between the NBS reported total and the total calculated from Sinopec-reported volumes. For each product, Sinopec provides data on production, import and export, allowing the calculation of "apparent consumption," which differs from the NBS calculation of consumption by the amount of stock change. As show in Table 4, NBS reports total consumption of Other Petroleum Products as 71.13 million tonnes, including a stock build of 1.98 million tonnes. Adjusting the Sinopec apparent consumption total of 73.96 million tonnes by the NBS reported stock change still leaves a 0.85 million tonne discrepancy between the Sinopec and NBS totals. The discrepancy may result from differences in scope between Sinopec and NBS reporting, or differences in calculating and reporting totals by the two organizations.

Table 4. Comparison of Sinopec and NBS data on Other Petroleum Products

"Other Petroleum Product"	Apparent Consumption (Mt)
Petroleum Asphalt	17.99
Lubricants	6.55
Lubricant base oil	1.24
Petroleum Coke	12.92
Naphtha	-0.74
Paraffin (Waxes and Polishes)	0.93
Solvent oil (Special Naphtha)	1.02
Detergents	0.39
Chemical light oil	33.64
Sinopec Reported Total	73.96
NBS Reported Stock Change	-1.98
NBS Reported Total	71.13
Discrepancy	0.85

Source: Sinopec 2009; CESY 2009

In terms of fuel end-use, China tracks energy consumption across seven end-use sectors, as shown in Table 5.

Table 5. China Energy End-Use Sectors

Full End-Use Sector Name	Short Reference
Farming, Forestry, Animal Husbandry, Fishery & Water Conservancy	Agriculture
Industry	Industry
Construction	Construction
Transport, Storage, Postal & Telecommunications Services	Transportation
Wholesale, Retail Trade and Catering Service	Commerce
Residential Consumption	Residential
Other [Public Sector]	Other

Source: CESY 2009

Emissions from fossil fuel consumption in the power sector, following the EIA methodology, are allocated among these seven end-use sectors according to their share of final electricity demand. Similarly, emissions from fossil fuel consumption in the production of commercial heat are allocated among the seven end-use sectors according to their share of final purchased heat demand. Losses from other transformation sectors (coal washing, petroleum refining, coking, and gas works) are all allocated to industry.

2.2 Adjust energy consumption data to eliminate double counting

EIA identifies 4 areas of possible double counting that are subject to adjustment.

Ethanol. Ethanol is not reported in China's energy balance table; no adjustment is necessary.

Synthetic Gas from Coal. China produces significant volumes of coke oven gas and other coal gases from gas works that are used primarily in the industrial and residential sectors. In the sectoral calculation of emissions, emissions from these products are calculated in the end-use consuming sector under "Coke and derived products." Although China accounts for these industries in the transformation sectors along with electric power and heat production, the losses from coking and gas works are all added to industrial sector emissions along with the emissions from final consumption of these products in industry, instead of being allocated among consumption sectors according to share of consumption as was done with electricity generation and heat production.

Still Gas to Pipelines. All still gas/refinery gas in China is reported as consumed in the industrial sector, and emissions are allocated to that sector accordingly.

Biogas. The majority of biogas consumed in China is from rural methane digesters and remains unaccounted for in the national energy balance. Data are not available on the possible amounts of recovered landfill methane gas that enters local gas pipeline networks.

2.3 Determine energy consumption data to account for fuel consumption in territories

China's national energy statistical data do not include energy consumption in its Special Administrative Regions of Macau and Hong Kong, nor in Taiwan, and these data are excluded in this study as well.

2.4 Convert physical fuel units to energy equivalents

The National Bureau of Standards reports its official energy data in two formats, both in original physical units and in units of standard coal. The National Bureau of Statistics annually publishes its list of standard conversion factors for each energy form, including its Lower Heating Value (LHV) and conversion factor to "coal equivalent" China's standard energy measure. One kilogram of coal equivalent is defined as 29.27 megajoules (MJ) (Table 6).

Table 6. NBS Standard Conversion Factors

Conversion Factors from Physical Unit to Coal Equivalent

Energy	Average Low Calorific Value	Conversion Factor
Raw Coal	20 908 kjoule / (5 000 kcal) / kg	0.7143 kgce / kg
Cleaned Coal	26 344 kjoule / (6 300 kcal) / kg	0.9000 kgce / kg
Other Washed Coal		
Middlings	8 363 kjoule / (2 000 kcal) / kg	0.2857 kgce / kg
Slimes	8 363 ~ 12 545 kjoule / (2 000 ~ 3 000kcal)/ kg	0.2857 ~ 0.4286 kgce / kg
Coke	28 435 kjoule / (6 800 kcal) / kg	0.9714 kgce / kg
Crude Oil	41 816 kjoule / (10 000 kcal) / kg	1.4286 kgce / kg
Fuel Oil	41 816 kjoule / (10 000 kcal) / kg	1.4286 kgce / kg
Gasoline	43 070 kjoule / (10 300 kcal) / kg	1.4714 kgce / kg
Kerosene	43 070 kjoule / (10 300 kcal) / kg	1.4714 kgce / kg
Diesel	42 652 kjoule / (10 200 kcal) / kg	1.4571 kgce / kg
Liquefied Petroleum Gas	50 179 kjoule / (12 000 kcal) / kg	1.7143 kgce / kg
Refinery Gas	46055 kjoule / (11 000 kcal) / kg	1.5714 kgce / kg
Natural Gas	38 931kjoule / (9 310 kcal) / cu. m	1.3300 kgce / cu. m
Coke Oven Gas	16 726 ~ 17 981kKjoule/ (4 000 ~ 4 300kcal)/ cu. m	0.5714 ~ 0.6143 kgce / cu. m
Other Coal Gas		
By Gas Furnace	5 227 kjoule / (1 250 kcal) / cu. m	0.1786 kgce / cu. m
By Heavy Oil Catalytic Cracking	19 235 kjoule / (4 600 kcal) / cu. m	0.6571 kgce / cu. m
By Heavy Oil Thermal Cracking	35 544 kjoule / (8 500 kcal) / cu. m	1.2143 kgce / cu. m
Coke Gas	16 308 kjoule / (3 900 kcal) / cu. m	0.5571 kgce / cu. m
By Pressure Gasification	15 054 kjoule / (3 600 kcal) / cu. m	0.5143 kgce / cu. m
Water Coal Gas	10 454 kjoule / (2 500 kcal) / cu. m	0.3571 kgce / cu. m
Coal Tar	33 453 kjoule / (8 000 kcal) / kg	1.1429 kgce / kg
Benzene	41 816 kjoule / (10 000 kcal) / kg	1.4286 kgce / kg
Heat (in calorific value)		0.03412 kgce / Mjoule (0.14286 kgce / 1000 kcal)
Electricity (in calorific value) (in coal equivalent)	3 596 kjoule / (860 kcal) / kW · h calculated by average coal input for thermal power generation in the year	0.1229 kgce / kW · h
Biomass Energy		
Night Soil	18 817 kjoule / (4 500 kcal) / kg	0.643 kgce / kg
Cow Dung	13 799 kjoule / (3 300 kcal) / kg	0.471 kgce / kg
Pig Dung	12 545 kjoule / (3 000 kcal) / kg	0.429 kgce / kg
Sheep/Donkey/Horse/Mule Dung	15 472 kjoule / (3 700 kcal) / kg	0.529 kgce / kg
Poultry Manure	18 817 kjoule / (4 500 kcal) / kg	0.643 kgce / kg
Soybean Stalk, Cotton Stalk	15 890 kjoule / (3 800 kcal) / kg	0.543 kgce / kg
Paddy Stalk	12 545 kjoule / (3 000 kcal) / kg	0.429 kgce / kg
Wheat stalk	14 635 kjoule / (3 500 kcal) / kg	0.500 kgce / kg
Maize Stalk	15 472 kjoule / (3 700 kcal) / kg	0.529 kgce / kg
Fireweed	13 799 kjoule / (3 300 kcal) / kg	0.471 kgce / kg
Leaves	14 635 kjoule / (3 500 kcal) / kg	0.500 kgce / kg
Firewood	16 726 kjoule / (4 000 kcal) / kg	0.571 kgce / kg
Biogas	20 908 kjoule / (5 000 kcal) / cu. m	0.714 kgce / cu. m

Source: NBS 2010a

The average heat value of most energy forms do not vary from year to year in the NBS reports, but there are slight annual variations in "Coke Oven Gas" and "Other Gases" (which is actually an aggregation of different gas types produced from different technology routes). By dividing the reported physical unit figure by the reported standard coal unit figure, the annual average conversion factor and assumed heat content can be derived.

Because NBS reports both physical units and standard coal units, this study directly uses the standard coal units as the measure of each energy form's energy content. The reported "ton coal equivalent" (tce) value is then multiplied by 29.27 MJ/kgce to convert all energy values to terajoules (TJ). Products reported by Sinopec ("Other Petroleum Products") are reported in original weight units of million tonnes; these are then converted to tce using the NBS standard, then to TJ.

2.5 Identify carbon emission coefficients and calculate total carbon content of each fuel type

Because the Chinese energy data are reported as Lower Heating Value, this study uses the carbon coefficients as reported in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Table 1-1, to calculate the carbon content of each fuel type (IPCC 1997a, IPCC 1997b). Carbon release from combustion is assumed to be 100% (Table 7). A weighted average carbon coefficient was calculated for 2008 for the constituent products of "Other Petroleum Products" to permit calculation of emissions when the constituents are not broken down in sectoral consumption calculations. The emissions coefficient for petroleum waxes follows EIA convention converted to a TJ basis.

Table 7. Carbon Coefficients

Name	t C/TJ
crude oil	20.0
natural gas liquids	17.2
gasoline	18.9
jet kerosene	19.5
other kerosene	19.6
shale oil	20.0
gas/diesel oil	20.2
residual fuel oil	21.1
LPG	17.2
ethane	16.8
naphtha	20.0
bitumen	22.0
lubricants	20.0
petroleum coke	27.5
refinery feedstock	20.0
still gas/refinery gas	18.2
petroleum waxes	18.8
coking coal	25.8

other bituminous coal	25.8
sub-bituminous coal	26.2
lignite	27.6
oil shale	29.1
other petroleum products (China 2008 weighted average)	21.6
coke oven/gas coke	29.5
natural gas (dry)	15.3
coke oven gas	13.0

Source: IPCC 1997a, IPCC 1997b; EIA 2006

2.6 Determine value of carbon sequestered in products

Calculation of the carbon sequestered in products follows EIA conventions for all the products listed in Table 3 (Other Petroleum Products) as well as for non-energy use of gasoline, kerosene, diesel (distillates) and fuel oil (residual), LPG, refinery gas/still gas, natural gas, and other coking products. In each case, the total carbon of the product consumed is calculated and the sequestration coefficient is applied.

Table 8. Sequestration Coefficients for Non-Energy Use Fuels and Non-Fuel Energy Products

Gasoline	0.50
Kerosene	0.50
Diesel Oil	0.50
Fuel Oil	0.50
LPG	0.80
Refinery/Still Gas	0.80
Petroleum asphalt	1.00
Lubricants	0.50
Lubricant base oil	0.50
Miscellaneous petroleum products	1.00
Pentanes plus	0.00
Petrochemical Feedstock (Chem Light Oil + Naphtha)	0.75
Petroleum coke	0.00
Naphtha (Petrochemical Feedstock)	0.00*
Paraffin (Waxes and Polishes)	1.00
Solvent oil (Special Naphthas)	0.00
Detergents	0.00
Chemical light oil (Petrochemical Feedstock)	0.75
Other Coking Products	0.75

*Set to zero as a net export; domestic use under Petrochemical Feedstock

Source: EIA 2006

For the products accounted for individually in the NBS data—gasoline, kerosene, diesel, fuel oil, LPG and refinery gas—the volume of each product listed as “feedstock or non-energy use” under the industrial

sector was used in the calculation of the sequestration amount following the EIA methodology. Although it is assumed that some portion of the non-fuel use of the distillate and residual oil was used in the chemical industry as is the case in the US, it cannot be confirmed from the NBS data directly.

Similarly, NBS listed only 45% of its "Other Petroleum Products" in the non-fuel or feedstock category, equivalent to the total volume of petrochemical feedstock (chemical light oil) accounted for in the category breakdown. It is assumed that the balance—asphalt, petroleum coke, lubricants, etc—is categorized under Industry and Construction energy use. For the purpose of calculating emissions and sequestration, however, the EIA conventions were followed for each constituent product.

NBS records about 55 million tonnes of raw coal, cleaned coal, other washed coal, briquettes, coke, coke oven gas and other coking products used for non-energy purposes. The majority of these products are assumed to be inputs to China's ammonia industry, which is largely coal based and consumed (in 2007) 55 million tonnes of coal, or to production of methanol for the chemical industry, which consumed 12 million tonnes of coal in 2007 (Wang, F., 2008). Consequently, it is assumed that the carbon in these applications is non-sequestering and 100% of the volume is emitted. "Other Coking Products", however, is assumed to be composed primarily of the tar by-products of the coking process and thus is mainly a sequestering use, following EIA convention.

NBS does not report natural gas flaring as a separate statistical category. It may wholly or in part be captured in the "Loss" category of the national energy balance, in which case the carbon emissions are included in the reference CO_2 calculation.

2.7 Subtract carbon in international bunker fuels

The IPCC excludes from the calculation of energy consumption both international and military bunker fuels. The EIA first includes international bunkers consumption in the calculation of national emissions, but then separately reports them and deducts them from the US total. This method has been applied in this study for China as well, but the NBS treatment of bunker fuels differs from IPCC definition, and thus the results are incomplete. The Chinese energy balance contains two international bunker categories: one is "China Airplanes & Ships Refueling Abroad," which is counted as an import (and thus should be treated as other countries' international bunkers in IPCC calculations), and "Foreign Airplanes & Ships Refueling in China," which is counted as an export. The NBS data do not indicate that amount of bunker fuels sold to Chinese airplanes and ships in China; this amount is contained within final demand in the transportation sector and cannot be further disaggregated from the NBS data alone. Similarly, military bunkers are recorded in the "Other" sector (which includes all public sector activities, including the military) and cannot be further disaggregated from the NBS data alone. A first order estimate of military jet fuel bunkers may be the kerosene (jet fuel) consumption in the "Other" sector.

2.8 Calculate and sum emissions for all fuel types and end uses

This report develops two calculations of China's CO_2 emissions: a "reference" calculation based on the IPCC reference top-down approach of estimating apparent energy consumption by fuel type, multiplied by the carbon emissions factor by fuel type, following EIA methodology on treatment of non-fuel emissions and sequestration. The second is a "sectoral" calculation" of emissions across end-use sectors,

by fuel type, and allocating electricity and heat emissions to each sector according to their share of consumption. Again, EIA convention is followed for treatment of non-fuel emissions and sequestration. The results of these calculations are presented in section 0.

2.9 Variances, Adjustments, Missing Data, and Incomplete Data

Primary Energy Calculation

In China's energy balance, by definition, Total Primary Energy Supply (TPES) is equivalent to Total Consumption (TC), which is the sum of consumption in transformation, losses and end-uses. Because transformation consumption is by convention reported as a negative, the identity is:

$$TPES \equiv |Transformation| + Losses + Final\ Consumption$$

Not unexpectedly in such a large energy system, total reported supply does not always equal total reported consumption, and NBS reports this discrepancy as "statistical difference". For most energy forms, the statistical difference is small, less than 0.5% of the total (0.001% in the case of crude oil and 0.45% for natural gas), but for coal, the difference was 2.1% in 2008, equal to over 60 million tonnes of raw coal. When reported consumption is greater than reported supply, the difference is expressed as a negative; when reported supply is greater than reported consumption, the difference is expressed as a positive.

In this study, for the purposes of calculating emissions from primary energy forms, the larger of the two numbers is used. In the case of coal, for example, the statistical difference is negative, and thus TC was used as the basis for emissions calculations. For crude oil and natural gas, where the statistical difference was positive, TPES was used for emissions calculations[1].

Bunker Adjustments

As discussed in section 2.7, a major variance in China energy statistics is its treatment and reporting of energy data related to international bunkers. In CESY 2009, NBS reports the secondary fuel consumed by China Airplanes & Ships Refueling Abroad as an import and deducts Foreign Airplanes & Ships Refueling in China as an export in calculating its total primary energy supply. As such, fuel use from Exports and Foreign Airplanes & Ships Refueling in China are expressed as negative values in the national energy balance. Following this China-specific convention of reporting exports and international bunkers, the NBS Total Primary Energy Supply (TPES) is calculated as:

$$\begin{aligned} TPES_{(NBS)} = \ & Import + Export + China\ Airplanes\ \&\ Ships\ Refueling\ Abroad \\ & + Foreign\ Airplanes\ \&\ Ships\ Refueling\ in\ China + Stock\ Change \end{aligned}$$

As a component of international bunkers defined by the IPCC as "fuels sold to and consumed by air or marine vessels engaging in international transport activities," the refueling of foreign and domestic airplanes and ships involved in international transport within a country is not usually reported

[1] In the emissions model, the statistical difference is tested through an "if" statement formula to automatically select TPES or TC as appropriate.

separately (IPCC 1997a). China, however, makes the distinction between these two components and reports "Foreign Airplanes & Ships Refueling in China" separately from "China Airplanes & Ships Fueling in China" before departing for international transport. In fact, China only reports the component of foreign vessels refueling domestically as an export and data on Chinese airplanes & ships fueling in China and leaving for international transport is missing. EIA, on the other hand, treats bunker fuels sales the same as other sales and includes carbon emissions from bunkers sales as part of the domestic energy consumption statistics. The international bunker portion is then listed separately as an adjustment item and subtracted from total emissions from domestic energy consumption. In applying this convention of subtracting bunker adjustments from total emissions, the Foreign Airplanes & Ships Refueling in China will need to be included in the domestic energy consumption calculation instead of being excluded as an export. In China's case, however, the reported international bunker adjustment is actually an underestimate of China's international bunker fuels (and thus the adjusted emissions is overestimated) because it does not include Chinese airplanes & ships fueling in China.

The bunker category China Airplanes & Ships Refueling Abroad is unique in that this is not usually reported in domestic data since it is included as national data in the country where the Chinese airplanes and ships refuel. In accordance with the EIA estimation and reporting methodology, China Airplanes & Ships Refueling Abroad need to be excluded from the TPES used for calculating domestic energy consumption and emissions because it is not a standard component of IPCC bunker fuel calculations and is already captured in the other country where the refueling occurs.

Thus, to align with the EIA conventions of reporting emissions and bunker adjustments, two adjustments to the NBS reported TPES are needed to include Foreign Airplanes & Ships Refueling in China and to exclude China Airplanes & Ships Refueling Abroad. Following the energy balance convention of expressing exports as negative values, the adjusted TPES, expressed as TPES', is calculated as:

$$TPES' = Import + Export - Foreign\ Airplanes\ \&\ Ships\ Refueling\ in\ China + Stock\ Change$$

which can also be expressed as:

$$TPES' = TPES_{(NBS)} - China\ Airplanes\ \&\ Ships\ Refueling\ Abroad - (\ 2\ x\ Foreign\ Airplanes\ \&\ Ships\ Refueling\ in\ China)$$

Since the two categories of bunker data are reported only for three secondary petroleum products of kerosene, diesel oil and fuel oil, the TPES adjustment is only applied to these three fuels.

A missing category of international bunkers not explicitly reported by NBS is fuel consumption from military bunkers involved in international transport. While there is no publicly available data sources for Chinese military bunkers, it is possible to estimate a first order of magnitude of military bunker fuel consumption using data from the national energy balance table. In the reporting of final energy consumption by sector, the other (public) sector includes the military and thus its kerosene consumption can be used as an approximation for military aircraft fuel consumption while diesel and fuel oil consumption can be used to estimate military marine vessels' fuel consumption. This will likely be an overestimate as it does not distinguish between military and non-military public use of aircrafts

and vessels, nor does it distinguish between the fuel consumed by military fleet used for domestic versus international transport. Due to the missing data, military bunkers are not included in the Chinese bunker adjustment in this model.

Carbon Steel Adjustments

China is the world's largest producer of steel so an additional China-specific adjustment for carbon sequestration in carbon steel manufactured through the Basic Oxygen Furnace (BOF) method has been added beyond the standard EIA methodology. Crude steel can be categorized as alloy steel or carbon steel, where carbon is the main alloying constituent, and is produced using pig iron from a blast furnace via the BOF method or from scrap metal using the Electric Arc Furnace (EAF) process. In other words, total crude steel production can be expressed by the two equations below:

Total Steel = BOF Steel + EAF Steel = (BOF Alloy + BOF Carbon) + (EAF Alloy + EAF Carbon)

Total Steel = Carbon Steel + Alloy Steel = (BOF Carbon + EAF Carbon) + (BOF Alloy + EAF Alloy)

In order to calculate the BOF carbon steel production where the primary carbon sequestration occurs, data inputs on total crude steel production, the BOF share of total steel production, the alloy share of total steel, and BOF share of alloy steel production are needed. While NBS reports total crude steel production in the China Statistical Yearbook (NBS, 2010b), Chinese industry reports and studies are needed to determine the BOF and alloy shares. The BOF carbon steel can then be calculated as:

BOF Carbon Steel = Total BOF Steel – BOF Alloy Steel

For 2008, the BOF carbon steel share of total crude steel production is estimated to be 81% (CISRI 2011, CASIS 2010), and the BOF share of alloy steel production 92% (CISRI 2011).[2]

After determining the total BOF produced carbon steel, the carbon sequestration can be estimated by dividing steel into two key categories with different average carbon contents: structural steel used for construction and infrastructure and product steel used in manufacturing appliances, equipment and other common products. Using the shares of structural and product steel and the estimated carbon content of each of the two types of steel, an overall average carbon mass content of carbon steel can be calculated. In essence, the carbon sequestered in carbon steel can be expressed as:

C_{seq} *= Total Steel Production (Mt) x BOF carbon steel share (%) x Average Steel Carbon Content (% of mass)*

The carbon sequestered in carbon steel is reported as part of the carbon sequestration in the non-energy use of coal.

EAF-produced carbon steel may also sequester a small amount of carbon. According to China's product standards, an average of 27.5% pig iron is added as input to EAF steel production in China (CISRI and CISA 2010). Although pig iron used in steelmaking is mandated to have at least 3.5% carbon content, it is

[2] The reported high share of BOF alloy steel production is questionable, given that the EAF process in China is elsewhere described as being "primarily for alloy steel and specialty steel production." The reported share may be the results of a statistical collection system that compiles information on enterprises "of designated scale and above," and thus may omit many of the small EAF plants (Mysteel 2009)

unclear how much of this carbon remains as "newly sequestered" carbon in the carbon steel output from the EAF process. Assuming that EAF output of carbon steel has the same average carbon content as BOF carbon steel (0.15%), and that 27.5% of the carbon was contributed from the pig iron input, then the additional sequestration would total 91,714 t CO_2, or 0.06% of total sequestered carbon.[3]

Sectoral Approach Adjustments

In the sectoral approach, several adjustments are made to capture adjustments made under the reference approach (e.g., bunkers) and to allocate certain fuel consumption and losses on a basis comparable to EIA sectoral reporting conventions.

The sectoral allocation of gasoline consumption needs to be adjusted because NBS has historically allocated transport fuels to the end-user (e.g., allocating gasoline to the residential sector for private transport) rather than to the actual end-use (transport) sector. Since EIA and other international energy statistical agencies allocate gasoline consumption to the transport sector, an adjustment is made to allocate all gasoline to the transport sector. The only exception is the portion of gasoline that is consumed by the industrial sector for non-energy use, which remains allocated to the industrial sector because is constitutes a portion of the distillates and residual petroleum used for non-energy purposes (petrochemicals) in which only a portion of the carbon is emitted. The transport sector final energy consumption of kerosene, diesel oil and fuel oil is further adjusted for the two Chinese bunker categories, with the addition of fuel consumed by Foreign Airplanes & Ships Refueling Abroad following EIA reporting conventions and the deduction of fuel consumed by China Airplanes & Ships Refueling Abroad.

The industrial sector final energy consumption is also adjusted to account for other transformation losses not captured in the reported final energy consumption or in the thermal power and heat transformation sectors. Since the losses associated with other transformation processes of coal washing, coking, petroleum refineries, gas works, and briquettes occur within energy processing industries, the calculated emissions from the net losses are allocated to the industrial sector. For each of these transformation processes, the emissions are calculated by multiplying the net transformation loss from the energy balance table by the carbon content of the fuel type of the dominant fuel loss. These emissions associated with the other transformation losses are then added to the final energy consumption of the industrial sector.

Incomplete Data and Emission Sources Excluded

In addition to energy-related emissions, another important source of CO_2 emissions is from industrial processes such as cement manufacture, limestone consumption, and aluminum manufacture, which is included in the EIA methodology. This is especially significant for China's industries, where process-related CO_2 emissions have been estimated to be as much as half of all direct CO_2 emissions from cement production (Wang, L., 2008). However, the significant amount of detailed process-related data needed to estimate CO_2 emissions from industrial process is not publicly available in China. Due to the

[3] The emissions model contains a calculation box for EAF carbon steel sequestration, but the results have not been added to the sequestration totals

lack of systematic reporting of data needed for estimating emissions, the CO_2 emissions produced and released during industrial processes are also excluded from both the reference and sectoral approaches. The one exception is the adjustment for sequestered carbon in carbon steel production, as discussed above. Another source of CO_2 emissions reported by EIA for the U.S. but not included in this inventory for China is the emissions from renewables, namely the combustion of municipal solid waste and the flash geothermal technology and dry steam used in geothermal power generation.

Because NBS and other public statistical sources do not report the volume of vented and flared natural gas, emissions from natural gas flaring cannot be estimated and is thus excluded from both the reference and sectoral approaches. While some of the emissions from natural gas flaring may be captured as losses in the balance table, it is not systematically estimated or included as part of the non-energy use emissions from natural gas.

Besides incomplete and missing data on natural gas flaring, there is also insufficient data on the specific end-uses and applications of non-energy use of petroleum products such as detergents, solvents and petroleum coke in China. Because certain products such as petroleum coke can have multiple applications ranging from use as a fuel in refineries and cement industries to the manufacture of graphite electrodes and anodes, the carbon emissions associated with petroleum coke consumption will likely differ depending on how it is used. Therefore, more data on the relative shares of applications and non-energy end-uses of these petroleum products will help determine if China-specific sequestration coefficients may be more appropriate than default EIA coefficients and should be developed to more accurately estimate CO_2 emissions

3. Results

3.1 Total Emissions

China's energy-related CO_2 emissions in 2008 estimated under the reference approach total 6665.8 Mt CO_2 after excluding 15.9 Mt of CO_2 from international bunker fuels (Table 1). As previously mentioned, this adjusted total CO_2 emissions is likely to be slightly overestimated due to missing adjustments for two categories of international bunkers: Chinese airplanes and ships involved in international transport that refuel in China and military bunkers. In terms of fuel, the largest share of unadjusted energy-related CO2 emissions is attributed to coal use with 82%, followed by petroleum at 15% and natural gas at 3%. Non-fuel emissions are responsible for 3.5% of total CO_2 emissions, while only 2% of unadjusted emissions are sequestered by non-fuel use of energy fuels (Figure 1).

Table 9. China's 2008 Total CO_2 Emissions from Energy Consumption: Reference Approach

ENERGY CONSUMPTION	EMISSIONS - T C	EMISSIONS - T CO_2
COAL	1,496,952,842	5,488,827,086
NATURAL GAS	48,638,365	178,340,673
PETROLEUM	276,699,464	1,014,564,701

ENERGY SUBTOTAL	**1,822,290,671**	**6,681,732,460**
	EMISSIONS - T C	**EMISSIONS - T CO_2**
NON-FUEL USE EMISSIONS[1]	*63,977,962*	*234,585,860*
NON-FUEL USE SEQUESTRATION[2]	*41,996,294*	*153,986,411*

ADJUSTMENTS TO ENERGY

	EMISSIONS - T C	**EMISSIONS - T CO_2**
BUNKER FUEL EMISSIONS	-4,341,951	-15,920,486
TOTAL ADJUSTMENTS	**-4,341,951**	**-15,920,486**

ADJUSTED TOTAL

	EMISSIONS - T C	**EMISSIONS - T CO_2**
ADJUSTED TOTAL	**1,817,948,720**	**6,665,811,974**

[1]Emissions from nonfuel uses are included in energy subtotal above.
[2]The carbon sequestered has been subtracted from emissions included in the energy subtotal above.

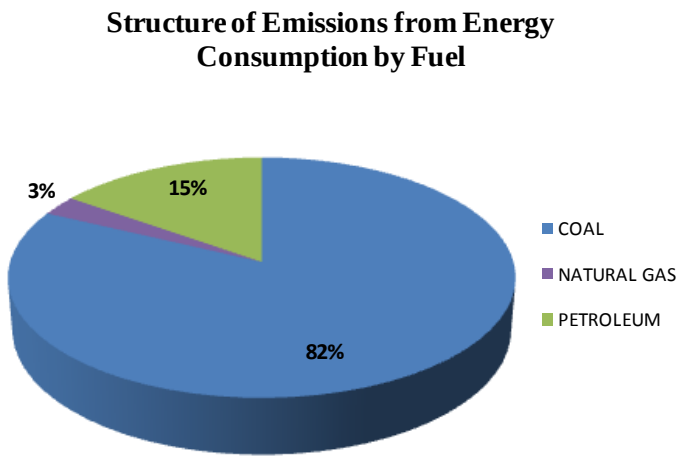


Figure 1. China's 2008 Total CO_2 Emissions from Energy Consumption by Fuel

From the sectoral approach, China's total energy-related CO_2 emissions in 2008 are estimated to be slightly higher at 6785.3 Mt CO_2 (Table 10). This difference in total estimated emissions between the reference and sectoral approach is likely the result of losses not captured in the transformation sector and statistical differences reported in the Chinese energy balance. Industry is responsible for the majority of energy-related emissions with 72% share, followed by 11% share from the residential sector and 8% from the transport and telecommunications sector (Figure 2). CO_2 emissions from each sector and the fuel shares of sectoral emissions are examined in detail in the section below.

Table 10. China's 2008 Total CO_2 Emissions from Energy: Sectoral Approach

ENERGY-RELATED EMISSIONS		
	EMISSIONS - T C	EMISSIONS - T CO_2
Agriculture	37,659,226.91	138,083,832.00
Industry	1,335,623,049.32	4,897,284,514.16
Construction	22,703,228.23	83,245,170.18
Transport & Telecomm	156,227,902.49	572,835,642.47
Commerce	36,388,244.49	133,423,563.11
Residential	196,797,340.14	721,590,247.18
Other (Public) Sector	65,146,860.85	238,871,823.10
TOTAL	**1,850,545,852.42**	**6,785,334,792.21**
Thermal Electricity[1]	690,855,316.36	2,533,136,159.97
Heat[2]	87,620,322.82	321,274,517.01

[1]Thermal electric power sector emissions are calculated on the basis of primary fossil fuel energy inputs and allocated to sectors based on their proportion of total demand. Emissions distributed to each end-use sector are included in the sectoral totals above.

[2]Heat sector emissions are also calculated using primary energy inputs and allocated to end-use sectors based on their proportion of total commercial heat demand. Heat-related emissions distributed to each end-use sector are included in the sectoral totals above.

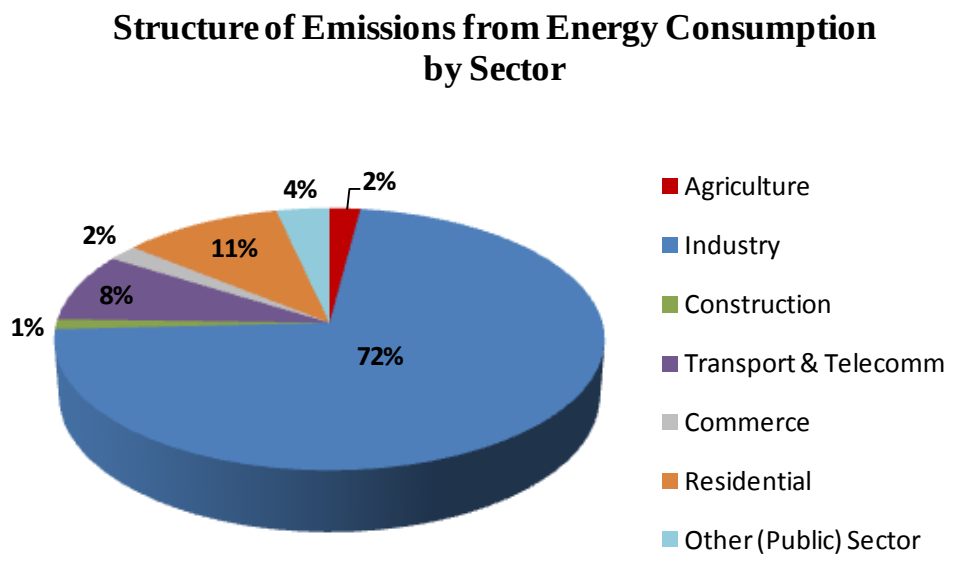


Figure 2. China's 2008 Total CO_2 Emissions from Energy by Sector

3.2 Sectoral Emissions

Agriculture

China's agricultural CO_2 emissions total 138 Mt CO_2 and originate primarily from electricity use, petroleum (namely diesel oil), coal, coke and other derivatives and heat (Table 11). The total CO_2 emissions include half from thermal electricity generation, a quarter from petroleum, and a quarter from coal and coke and derivatives (Figure 3).

Table 11. China's 2008 CO_2 Emissions from Energy: Agriculture

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO2
TOTAL	**37,659,226.91**	**138,083,832.00**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO2
Coal	**8,750,102.58**	**32,083,709.46**
Coke and Other Derivatives	**445,765.24**	**1,634,472.53**
Petroleum	**9,522,987.85**	**34,917,622.12**
Crude Oil	0.00	0.00
Gasoline	0.00	0.00
Kerosene	10,582.00	38,800.67
Diesel Oil	9,467,178.30	34,712,987.08
Fuel Oil	13,234.76	48,527.47
LPG	31,992.79	117,306.90
Refinery Gas	0.00	0.00
Other Petroleum Products	0.00	0.00
Natural Gas	**0.00**	**0.00**
Heat[1]	**28,100.17**	**103,033.96**
Electricity[2]	**18,912,271.07**	**69,344,993.94**

[1]Share of heat sector's CO_2 emissions weighted by agricultural sector's share of final energy consumption of heat.
[2]Share of thermal electricity sector's CO_2 emissions weighted by agricultural sector's share of final energy consumption of electricity.

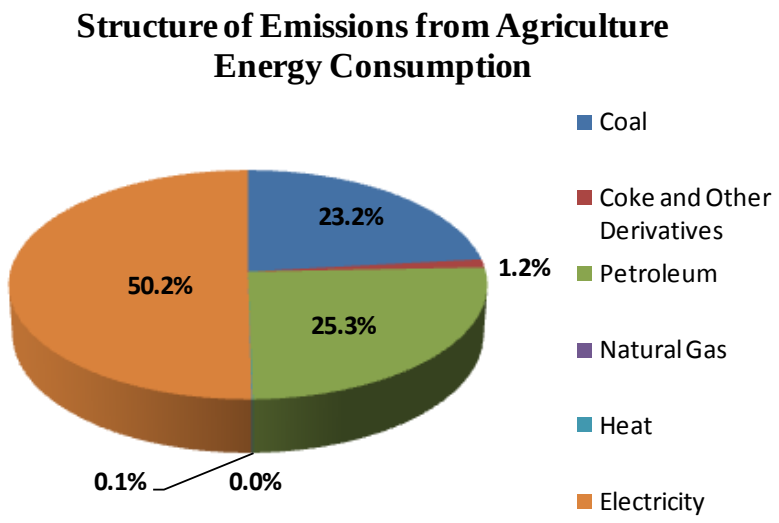


Figure 3. China's 2008 Agriculture CO_2 Emissions by Major Fuels

Industry

China's 2008 energy-related CO_2 emissions in the industrial sector are estimated to total 4897.3 Mt CO_2 (Table 12). This estimated total includes two specific adjustments: carbon sequestered by carbon steel and emissions from other transformation sector losses. This estimate does not include process-based emissions (with the exception of carbon steel). Emissions from electricity use comprise 37% of total industry emissions, while the remainder is mostly from direct fuel use and non-fuel use of coal, petroleum and natural gas (Figure 4). Coal and coke and derivatives consumption together contribute half of energy-related industrial CO_2 emissions, followed by petroleum and heat. The emissions from other transformation sector losses comprise of only 2.5% of industrial CO_2 emissions.

Table 12: China's 2008 CO_2 Emissions from Energy: Industry

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO2
TOTAL	**1,335,623,049.32**	**4,897,284,514.16**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO2
Coal	**367,697,859.82**	**1,348,225,486.02**
Coke and Other Derivatives	**285,734,341.61**	**1,047,692,585.90**
Petroleum	**66,083,737.05**	**242,307,035.85**
Crude Oil	9,975,206.80	36,575,758.27
Gasoline	76,556.53	280,707.27
Kerosene	388,163.17	1,423,264.97

Diesel Oil	19,900,181.22	72,967,331.13
Fuel Oil	13,431,547.74	49,249,008.38
LPG	4,256,127.83	15,605,802.03
Refinery Gas	7,408,167.54	27,163,280.97
Other Petroleum Products	10,647,786.23	39,041,882.84
Natural Gas	**24,822,785.91**	**91,016,881.66**
Heat[1]	**61,733,304.90**	**226,355,451.31**
Electricity[2]	**495,715,559.07**	**1,817,623,716.58**
Other Transformation Sector Losses[3]	**33,835,460.96**	**124,063,356.86**

[1]Share of heat sector's CO_2 emissions weighted by industrial sector's share of final energy consumption of heat.
[2]Share of thermal electricity sector's CO_2 emissions weighted by industrial sector's share of final energy consumption of electricity.
[3]Other transformation sector losses include coal washing, coking, petroleum refining, gas works and briquettes.

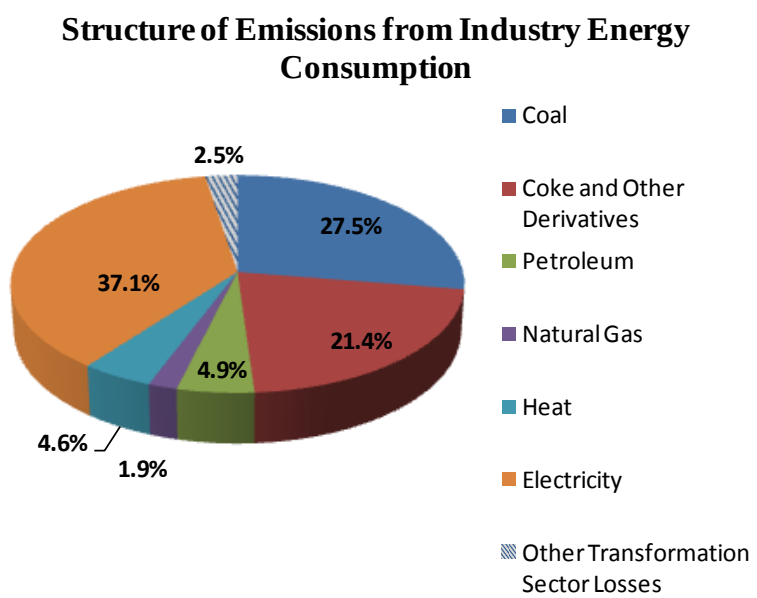


Figure 4. China's 2008 Industry CO_2 Emissions by Major Fuels

Construction

As a relatively small sector in terms of energy consumption, the Chinese construction sector's energy-related emissions totaled only 82.2 Mt CO_2 in 2008 (Table 13). Nearly half of the emissions are from petroleum fuel use, particularly in the use of other petroleum products and diesel oil (Figure 5). It is likely that the majority of asphalt consumption—and thus carbon sequestration—is recorded in this sector. Electricity and coal are also major sources of construction CO_2 emissions.

Table 13. China's 2008 CO_2 Emissions from Energy: Construction

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO2
TOTAL	**22,703,228.23**	**83,245,170.18**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO2
Coal	**3,474,707.50**	**12,740,594.17**
Coke and Other Derivatives	**89,734.81**	**329,027.64**
Petroleum	**11,077,927.11**	**40,619,066.09**
Crude Oil	0.00	0.00
Gasoline	0.00	0.00
Kerosene	81,212.65	297,779.71
Diesel Oil	3,194,483.00	11,713,104.35
Fuel Oil	332,633.74	1,219,657.03
LPG	53,165.25	194,939.23
Refinery Gas	0.00	0.00
Other Petroleum Products	7,416,432.48	27,193,585.76
Natural Gas	**58,967.15**	**216,212.87**
Heat[1]	**170,051.68**	**623,522.81**
Electricity[2]	**7,831,839.98**	**28,716,746.60**

[1]Share of heat sector's CO_2 emissions weighted by construction sector's share of final energy consumption of heat.
[2]Share of thermal electricity sector's CO_2 emissions weighted by construction sector's share of final energy consumption of electricity.

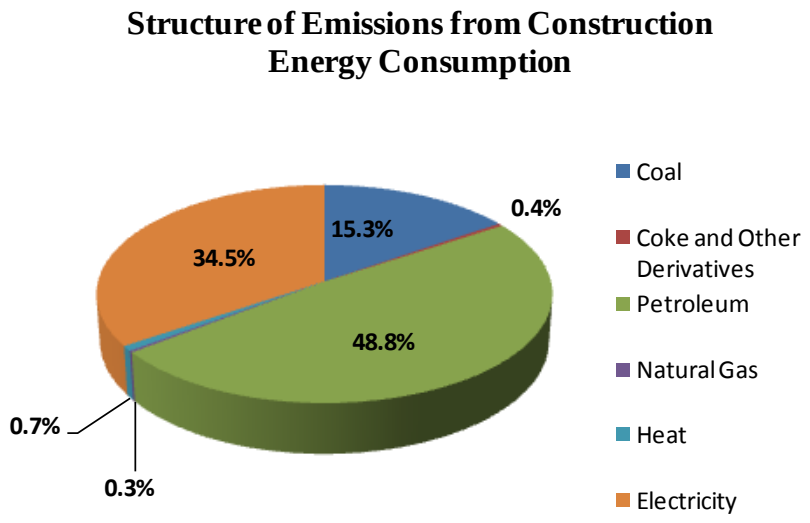


Figure 5. China's 2008 Construction Sector CO_2 Emissions by Major Fuels

Transport, Post and Telecommunications

Unlike many other countries including the US, China reports its transport energy consumption and related CO_2 emissions in the same sector as postal service and telecommunications. The transport, post and telecommunications sector also includes two emissions adjustments: the addition for international bunkers (which is not captured in final energy consumption reporting) and the reallocation of gasoline from all other sectors except industrial non-energy use sectors to this sector. In 2008, the adjusted CO_2 emissions for this sector totaled 572.8 Mt, with transport responsible for the majority of emissions as 87% of emissions can be attributed to petroleum fuels (Table 14). This includes significant emissions from diesel oil and gasoline for road transport, as well as kerosene and fuel oil for air and water transport. In contrast, a notable portion of the 8% share of emissions from electricity is likely from telecommunications services, including data centers (Figure 6).

Table 14. China's 2008 CO_2 Emissions from Energy: Transport, Post and Telecommunications

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO_2
TOTAL	**156,227,902.49**	**572,835,642.47**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO_2
Coal	**3,834,629.70**	**14,060,308.92**
Coke and Other Derivatives	**5,506.36**	**20,189.97**
Petroleum	**135,809,225.07**	**497,967,158.59**
Crude Oil	0.00	0.00
Gasoline	49,870,367.85	182,858,015.45
Kerosene	9,705,961.40	35,588,525.13
Diesel Oil	66,051,680.39	242,189,494.78
Fuel Oil	9,709,287.57	35,600,721.07
LPG	471,927.86	1,730,402.16
Refinery Gas	0.00	0.00
Other Petroleum Products	0.00	0.00
Natural Gas	**3,761,984.78**	**13,793,944.20**
Heat[1]	**625,118.84**	**2,292,102.41**
Electricity[2]	**12,191,437.74**	**44,701,938.37**

[1]Share of heat sector's CO_2 emissions weighted by transport, post and telecommunication sector's share of final energy consumption of heat.
[2]Share of thermal electricity sector's CO_2 emissions weighted by transport, post and telecommunication sector's share of final energy consumption of electricity.

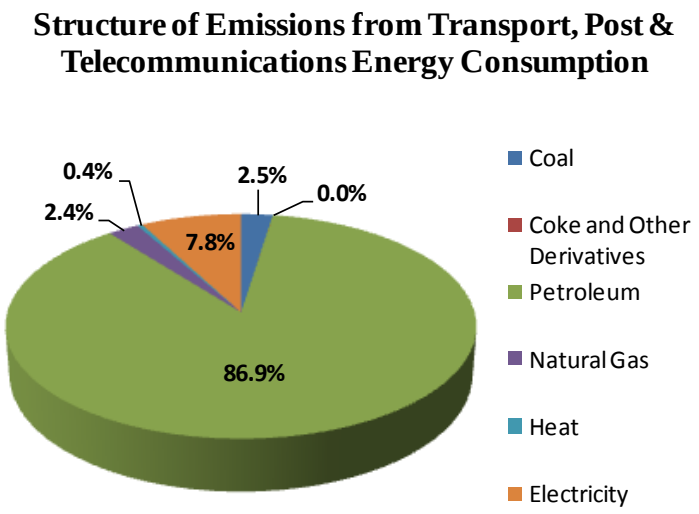


Figure 6. China's 2008 Transport, Post and Telecommunications Sector CO_2 Emissions by Major Fuels

Commerce

China's commercial sector covers wholesale, retail and catering services with total energy-related CO_2 emissions estimated at 133.4 Mt CO_2 in 2008 (Table 15). The majority of emissions are from thermal electricity use, followed by coal, petroleum and heat (Figure 7).

Table 15. China's 2008 CO_2 Emissions from Energy: Commerce

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO_2
TOTAL	**36,388,244.49**	**133,423,563.11**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO_2
Coal	**10,290,023.93**	**37,730,087.73**
Coke and Other Derivatives	**187,020.92**	**685,743.39**
Petroleum	**1,988,922.53**	**7,292,715.95**
Crude Oil	0.00	0.00
Gasoline	0.00	0.00
Kerosene	174,854.95	641,134.81
Diesel Oil	1,315,735.17	4,824,362.30
Fuel Oil	55,144.85	202,197.78
LPG	443,187.56	1,625,021.05
Refinery Gas	0.00	0.00
Other Petroleum Products	0.00	0.00
Natural Gas	**1,057,239.23**	**3,876,543.85**

Heat[1]	**1,172,798.34**	**4,300,260.56**
Electricity[2]	**21,692,239.54**	**79,538,211.64**

[1]Share of heat sector's CO_2 emissions weighted by commerce sector's share of final energy consumption of heat.
[2]Share of thermal electricity sector's CO_2 emissions weighted by commerce sector's share of final energy consumption of electricity.

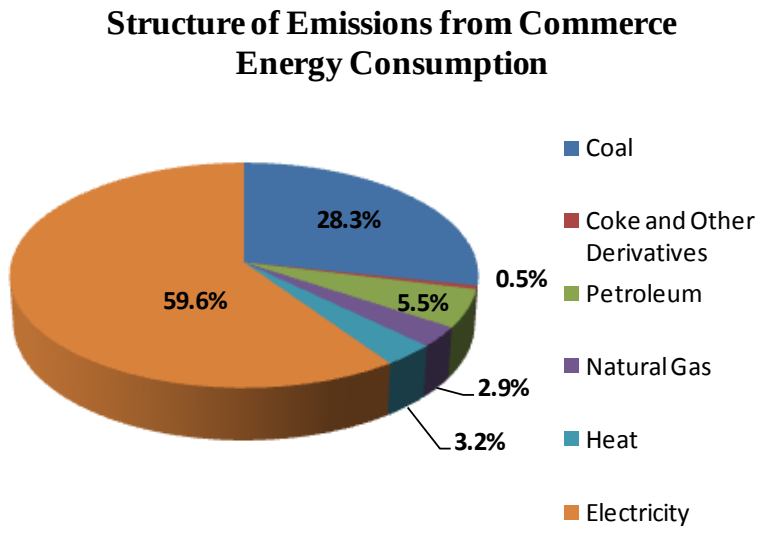


Figure 7. China's 2008 Commerce Sector CO_2 Emissions by Major Fuels

Residential

In 2008, energy-related CO_2 emissions in China's residential sector are estimated to total 721.6 Mt CO_2, including 48% from thermal electricity and 26% from coal use (Table 16). The residential sector is also the second highest end-use sector after industry for CO_2 emissions from commercial heat with 11%, followed by 9% of total emissions from petroleum, 5% from natural gas and 2% from coke and derivatives (Figure 8).

Table 16. China's 2008 CO_2 Emissions from Energy: Residential

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO_2
TOTAL	**196,797,340.14**	**721,590,247.18**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO_2
Coal	**50,479,751.54**	**185,092,422.30**
Coke and Other Derivatives	**3,074,292.63**	**11,272,406.30**
Petroleum	**17,782,145.08**	**65,201,198.62**
Crude Oil	0.00	0.00

Gasoline	0.00	0.00
Kerosene	106,499.85	390,499.45
Diesel Oil	5,100,941.88	18,703,453.55
Fuel Oil	0.00	0.00
LPG	12,574,703.35	46,107,245.63
Refinery Gas	0.00	0.00
Other Petroleum Products	0.00	0.00
Natural Gas	**10,132,959.95**	**37,154,186.49**
Heat[1]	**21,601,529.69**	**79,205,608.85**
Electricity[2]	**93,726,661.26**	**343,664,424.61**

[1]Share of heat sector's CO_2 emissions weighted by residential sector's share of final energy consumption of heat.
[2]Share of thermal electricity sector's CO_2 emissions weighted by residential sector's share of final energy consumption of electricity.

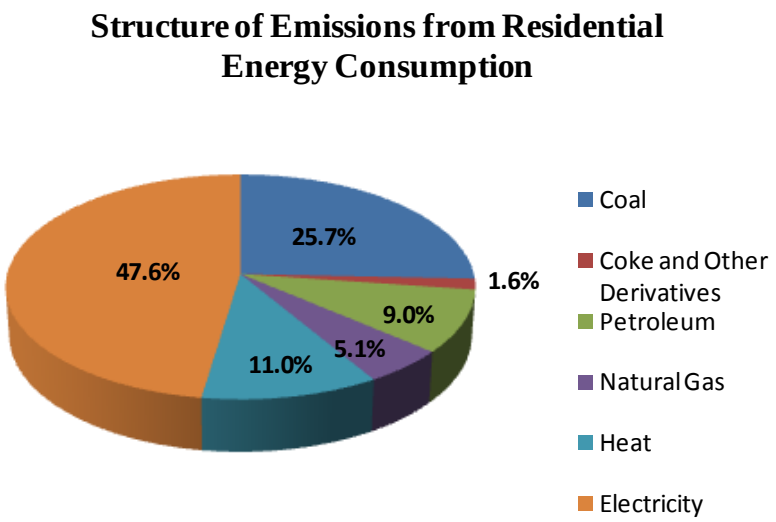


Figure 8. China's 2008 Residential Sector CO_2 Emissions by Major Fuels

Other (Public) Sector

China's other (public) sector is estimated to emit 238.9 Mt CO_2 in 2008, with the bulk coming from thermal electricity use (60%), coal and petroleum (16% each) and smaller shares from heat and natural gas. This sector's fuel consumption includes that of military bunkers, which is not included in the bunker adjustment due to the lack of data.

Table 17. China's 2008 CO_2 Emissions from Energy: Other (Public) Sector

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO_2
TOTAL	**65,146,860.85**	**238,871,823.10**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO_2
Coal	**10,116,379.34**	**37,093,390.90**
Coke and Other Derivatives	**100,035.07**	**366,795.25**
Petroleum	**10,609,829.51**	**38,902,708.19**
Crude Oil	0.00	0.00
Gasoline	0.00	0.00
Kerosene	217,550.80	797,686.26
Diesel Oil	9,923,183.76	36,385,007.11
Fuel Oil	83,474.30	306,072.45
LPG	385,620.65	1,413,942.37
Refinery Gas	0.00	0.00
Other Petroleum Products	0.00	0.00
Natural Gas	**1,245,890.02**	**4,568,263.41**
Heat[1]	**2,289,419.21**	**8,394,537.10**
Electricity[2]	**40,785,307.70**	**149,546,128.24**

[1]Share of heat sector's CO_2 emissions weighted by other(public) sector's share of final energy consumption of heat.
[2]Share of thermal electricity sector's CO_2 emissions weighted by other(public) sector's share of final energy consumption of electricity.

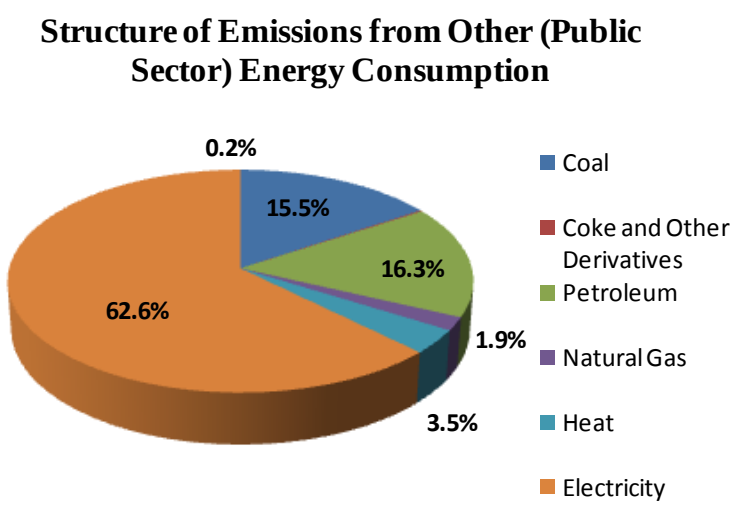


Figure 9. China's 2008 Other (Public) Sector CO_2 Emissions by Major Fuels

Thermal Electricity

As a major energy source for many end-use sectors, thermal electricity emits a significant portion of China's energy-related CO_2 emissions with 2533.1 Mt CO_2 emitted in 2008 (Table 18). The vast majority of CO_2 emissions related to energy use in thermal electricity generation is from coal with a 98% share of emissions, followed by petroleum at less than 1% and coal and coke at a combined share of 1.2% (Figure 10).

Table 18. China's 2008 CO_2 Emissions from Energy: Thermal Electricity Generation

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO_2
TOTAL	**690,855,316.36**	**2,533,136,159.97**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO_2
Coal	**677,412,133.91**	**2,483,844,490.99**
Coke and Other Derivatives	**3,189,409.79**	**11,694,502.57**
Petroleum	**5,371,412.10**	**19,695,177.71**
Crude Oil	74,181.58	271,999.14
Gasoline	0.00	0.00
Kerosene	0.00	0.00
Diesel Oil	1,594,960.50	5,848,188.51
Fuel Oil	3,066,318.36	11,243,167.30
LPG	0.00	0.00
Refinery Gas	298,769.68	1,095,488.84
Other Petroleum Products	337,181.98	1,236,333.91
Natural Gas	**4,882,360.55**	**17,901,988.70**

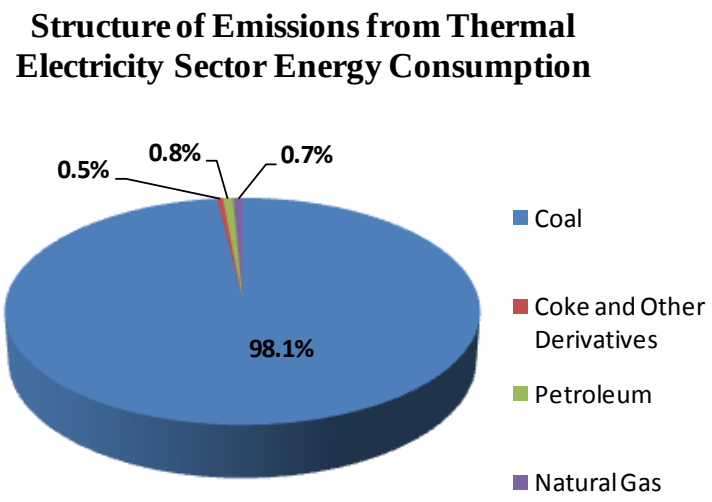


Figure 10. China's 2008 Thermal Electricity Sector CO_2 Emissions by Major Fuels

Heat

Commercial heat is primarily supplied as a secondary energy form to the industrial and residential sectors, followed by smaller uses in other (public) sector and transport sectors. In 2008, fuel consumption for producing commercial heat is estimated to total 321.3 Mt CO_2 (Table 19). Coal is the predominant fuel source of China's heat supply and contributed almost 94% of total CO_2 emissions from heat, followed by petroleum, natural gas and coke and derivatives at 4%, 2% and 1%, respectively (Figure 11).

Table 19. China's 2008 CO_2 Emissions from Energy: Heat Production

TOTAL ENERGY EMISSIONS		
	EMISSIONS- T C	EMISSIONS -T CO_2
TOTAL	**87,620,322.82**	**321,274,517.01**
Energy Emissions		
	EMISSIONS- T C	EMISSIONS -T CO_2
Coal	**82,114,790.47**	**301,087,565.05**
Coke and Other Derivatives	**717,381.72**	**2,630,399.65**
Petroleum	**3,513,507.27**	**12,882,860.00**
Crude Oil	7,945.04	29,131.81
Gasoline	0.00	0.00
Kerosene	0.00	0.00
Diesel Oil	0.00	0.00
Fuel Oil	1,145,160.01	4,198,920.05

LPG	53,424.17	195,888.61
Refinery Gas	1,462,121.40	5,361,111.80
Other Petroleum Products	844,856.65	3,097,807.72
Natural Gas	**1,274,643.36**	**4,673,692.30**

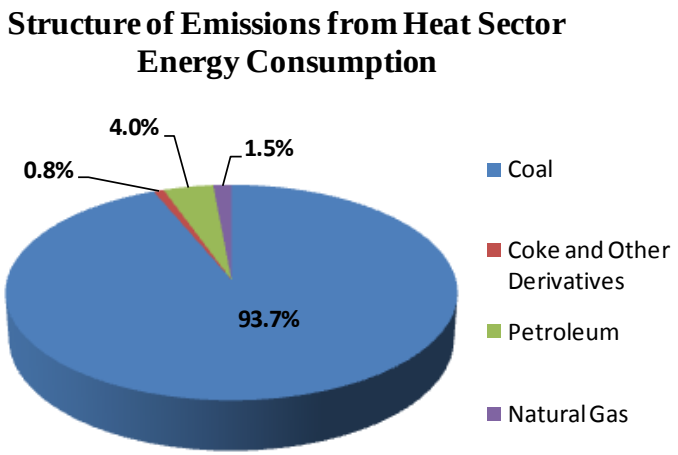


Figure 11. China's 2008 Heat Sector CO_2 Emissions by Major Fuels

3.3 Emissions from Nonfuel Use of Energy

Of the total estimated CO_2 emissions for China in 2008, a portion derive from nonfuel uses of fossil fuels, rather than from combustion during direct fuel consumption. The nonfuel (and feedstock) use of fuels is accounted for in the industrial sector, although as noted in the discussion on sequestration (section 3.4), there is apparent consumption of non-fuel petroleum products in other sectors, and some of these products, such as lubricants, result in carbon emissions as well. Nonfuel emissions captured in the industrial sector include coal, coke and coking products; crude oil, gasoline, kerosene, diesel oil, fuel oil, LPG, refinery gas and other petroleum products; and natural gas. In 2008, the CO_2 emissions from nonfuel use totaled 234.6 Mt CO_2, or 3.5% of the total adjusted emissions of 6666 Mt CO_2 (Table 20). The majority of the nonfuel emissions are from industrial non-energy use of raw coal (34%), coke (16%), petroleum coke (19%), chemical light oil (11%) and lubricants (4%), and natural gas (10%) (Figure 12).

Table 20. China's 2008 CO_2 Emissions from Nonfuel Use of Energy Fuels

	EMISSIONS - T C	EMISSIONS -T CO_2
COAL	34,078,169.12	124,953,286.76
PETROLEUM	23,694,096.31	86,878,353.14
NATURAL GAS	6,205,696.48	22,754,220.42
Total Non-fuel Emissions	63,977,961.90	234,585,860.31

	Nonfuel % of Total Emissions	3.5%

CARBON EMISSIONS FROM NON-FUEL USE- COAL

	EMISSIONS - T C	EMISSIONS -T CO_2
Raw Coal	21,711,191.75	79,607,703.10
Cleaned Coal	815,200.72	2,989,069.29
Washed Coal	1,060,707.63	3,889,261.32
Briquettes	59,556.79	218,374.91
Coke	9,920,869.93	36,376,523.08
Coke Oven Gas	111,887.83	410,255.37
Other Gas	0.00	0.00
Other Coking Products	398,754.46	1,462,099.67
	Nonfuel % of Total Coal Emissions	2.3%

CARBON EMISSIONS FROM NON-FUEL USE - PETROLEUM

	EMISSIONS - T C	EMISSIONS -T CO_2
Gasoline	76,556.53	280,707.27
Kerosene	24,030.92	88,113.36
Diesel Oil	189,850.80	696,119.61
Fuel Oil	333,577.37	1,223,117.02
LPG	92.88	340.55
Still Gas	12.04	44.15
Petroleum Asphalt	0.00	0.00
Lubricants	2,739,031.63	10,043,115.98
Lubricant base oil	519,271.09	1,903,993.99
Miscellaneous petroleum products	0.00	0.00
Pentanes plus	0.00	0.00
Petrochemical Feedstock	0.00	0.00
Petroleum Coke	12,082,537.50	44,302,637.50
Special Naphtha	-634,444.20	-2,326,295.40
Paraffin (Waxes and Polishes)	0.00	0.00
Solvent oil (Special Naphtha)	855,806.26	3,137,956.27
Detergents	274,120.00	1,005,106.67
Chemical light oil	7,233,653.50	26,523,396.17
Subtotal	**23,694,096.31**	**86,878,353.14**
	Nonfuel % of Total Petroleum Emissions	8.6%

CARBON EMISSIONS FROM NONFUEL USE - NATRUAL GAS

	EMISSIONS -T C	EMISSIONS -T CO_2
Natural Gas Flaring	0.00	0.00
Natural Gas	6,205,696.48	22,754,220.42
	Nonfuel % of Total Natural Gas Emissions	12.8%

Note: Emissions from nonfuel use of energy fuels are included in the emissions from energy consumption tables.

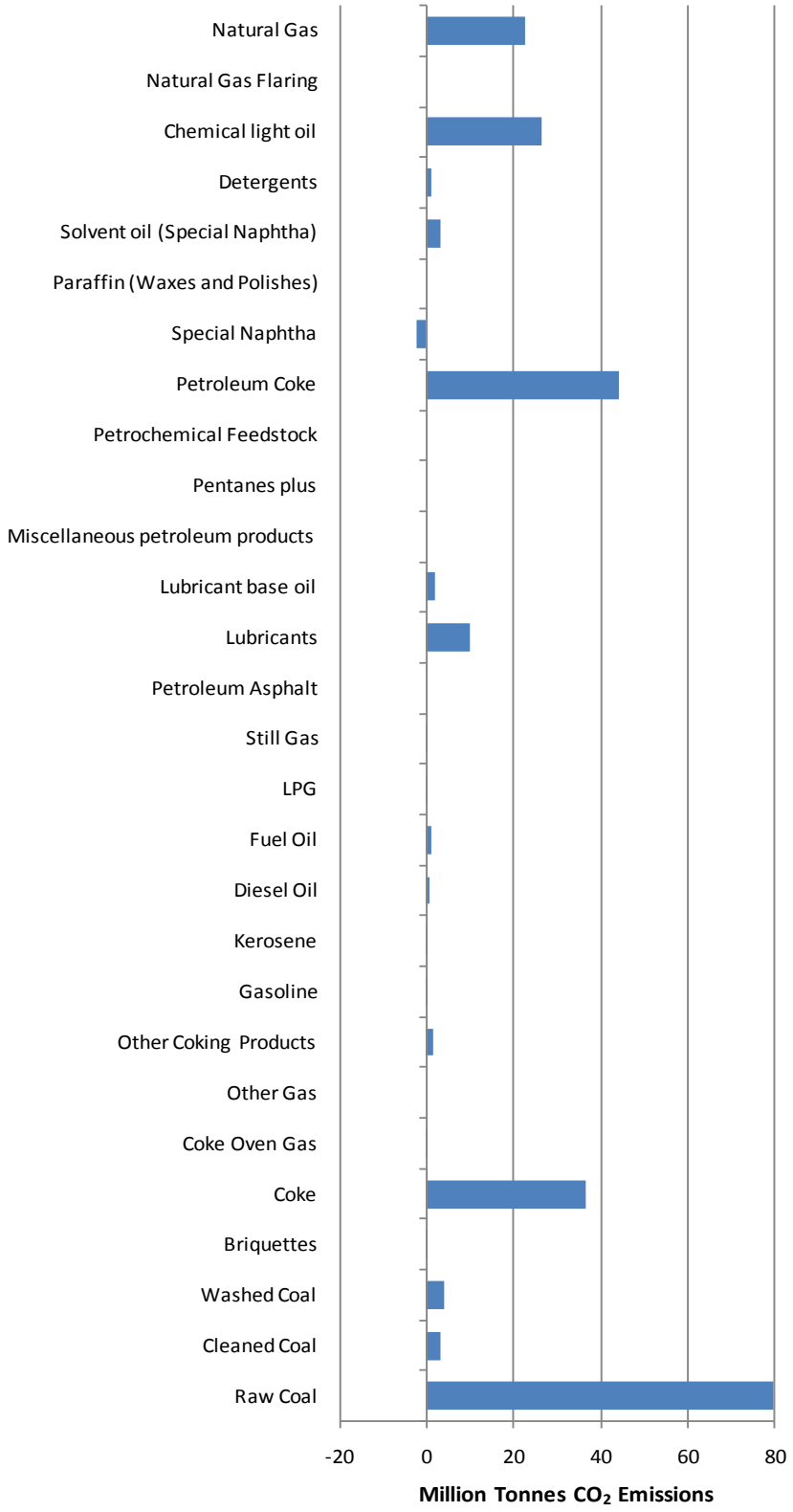


Figure 12. China's 2008 CO_2 Emissions from Non-fuel Use of Energy by Fuel Type

3.4 Carbon Sequestration

In estimating China's total CO_2 emissions for 2008, the carbon sequestered in the non-energy use of energy inputs including carbon steel and other coking products, and secondary petroleum products including plastics and other feedstocks are estimated and then deducted from total emissions. CO_2 sequestration is estimated to total 154 Mt CO_2 in 2008, or 2.3% of total carbon (Table 21). The majority (95% share) of sequestered carbon is from non-fuel use of petroleum products, with most of the carbon stored in chemical light oil, petroleum asphalt and lubricants (Figure 13). The remaining 5% of stored carbon is sequestered in the non-energy use of other coking products and carbon steel. Because all of the non-energy use of natural gas in China is in ammonia production with a carbon storage coefficient of zero, there is no carbon storage from non-energy use natural gas.

Table 21. China's 2008 Carbon Sequestration by Nonfuel Use of Energy Fuels

	SEQUESTRATION- T C	SEQUESTRATION -T CO_2
COAL	1,807,450.09	6,627,316.98
PETROLEUM	40,188,843.93	147,359,094.40
NATURAL GAS	0.00	0.00
Total Sequestration	41,996,294.01	153,986,411.38
	% of Total Carbon	**2.3%**
CARBON SEQUESTRATION FROM NON-FUEL USE- COAL		
	SEQUESTRATION- T C	SEQUESTRATION -T CO_2
Other Coking Products	1,196,263.37	4,386,299.02
Carbon in Steel	611,186.72	2,241,017.96
	% of Total Coal Carbon	**0.12%**
CARBON SEQUESTRATION FROM NON-FUEL USE - PETROLEUM		
	SEQUESTRATION- T C	SEQUESTRATION -T CO_2
Gasoline	76,556.53	76,556.53
Kerosene	24,030.92	24,030.92
Diesel Oil	189,850.80	189,850.80
Fuel Oil	333,577.37	333,577.37
LPG	371.51	92.88
Still Gas	48.17	12.04
Petroleum Asphalt	13,850,529.00	50,785,273.00
Lubricants	2,739,031.63	10,043,115.98
Lubricant base oil	519,271.09	1,903,993.99
Miscellaneous petroleum products	0.00	0.00
Pentanes plus	0.00	0.00
Petrochemical Feedstock	0.00	0.00
Petroleum Coke	0.00	0.00
Special Naphtha	0.00	0.00
Paraffin (Waxes and Polishes)	754,616.42	2,766,926.86

Solvent oil (Special Naphtha)	0.00	0.00
Detergents	0.00	0.00
Chemical light oil	21,700,960.50	79,570,188.50
Subtotal	**40,188,843.93**	**145,693,618.86**
	% of Total Petroleum Carbon	**12.7%**
CARBON SEQUESTRATION FROM NONFUEL USE - NATRUAL GAS		
	SEQUESTRATION- T C	SEQUESTRATION -T CO_2
Natural Gas Flaring	0.00	0.00
Non-Energy Use Natural Gas	0.00	0.00
	% of Total Natural Gas Carbon	**0.0%**

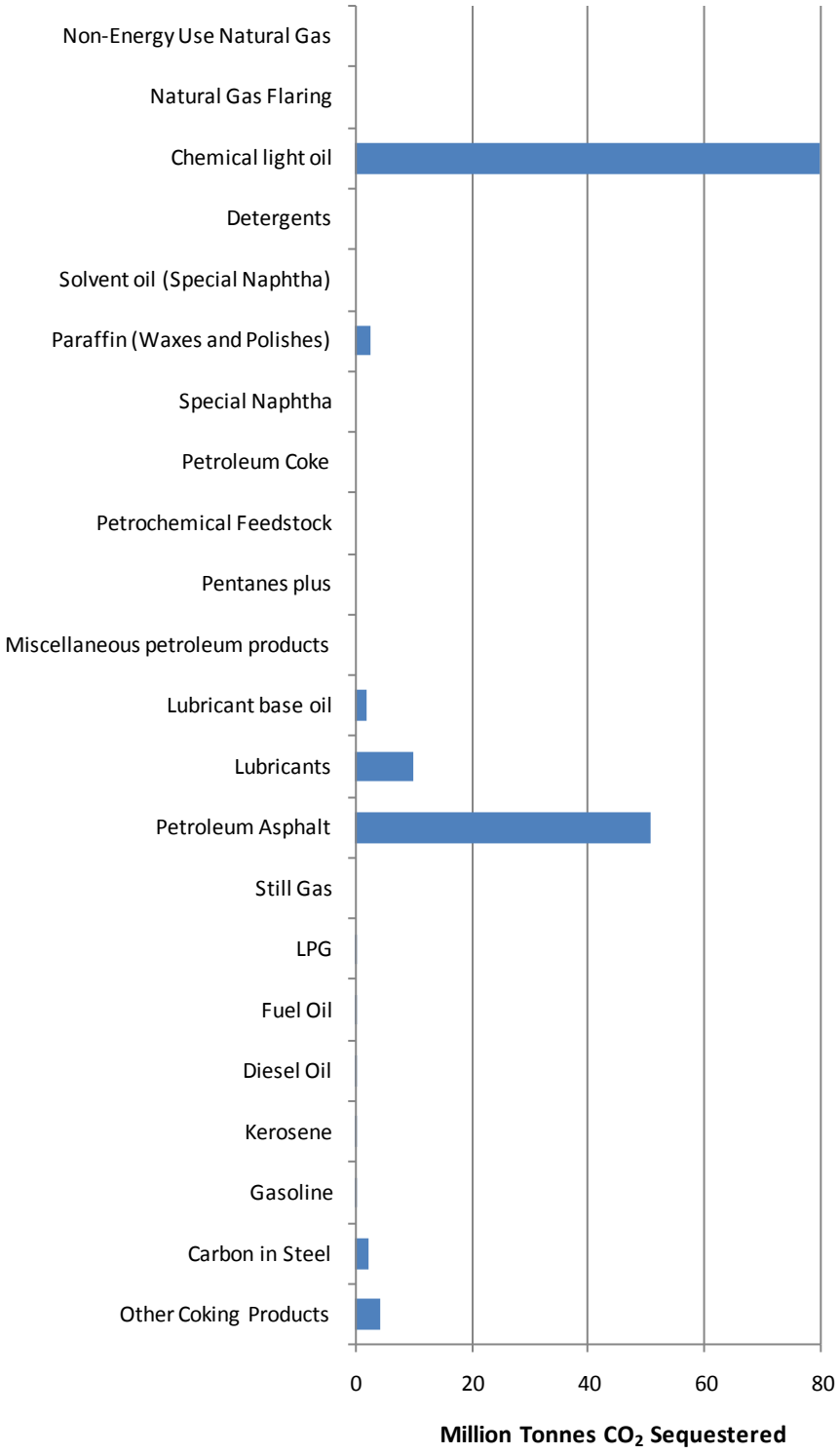


Figure 13. China 2008 CO_2 Sequestration by Nonfuel Uses of Energy Fuels by Fuel Type

4. Conclusions and Areas for Improvement

This study assessed the applicability of the EIA methodology for estimating China's 2008 CO_2 emissions using published Chinese data. In applying the US estimation and reporting methodology to Chinese data, several areas of key statistical differences and data problems are highlighted. While the EIA method of calculating and reporting energy-related emissions by fuels and by sector can be applied using statistics from primary and secondary Chinese data sources, adjustments to account for significant differences between US and Chinese energy statistics are necessary. The total primary energy supply data for kerosene, diesel and fuel oil needs to be adjusted in order to exclude Chinese ships refueling abroad data (reported by other countries) and to include foreign ships refueling in China. China's important role as a global steel producer also suggests that carbon steel needs to be considered as a source of carbon sequestration and included in estimating total emissions. In the sectoral approach, fuels (gasoline) and emissions (bunkers and other transformation losses) must be reallocated to align with US conventions for reporting sectoral emissions.

In addition to the necessary adjustments to Chinese data for applying the EIA emissions inventory methodology, there are several remaining areas for improvement that will impact the accuracy and comparability of the emissions estimates. First, data insufficiencies precluded the estimation of industrial process-based emissions such as those from cement production, limestone consumption and natural gas production. Although US industrial process emissions only had a 2% share of total emissions in 2008, this share is higher in China where industrial activity dominates the economy. Because of the complexity surrounding various industrial processes that emit CO_2, more data and research into industrial processes outside of the scope of this study are prerequisites for appropriately estimating total CO_2 emissions. Similarly, emissions from natural gas flaring, which is omitted in this study due to insufficient data, is another area where data improvements can help increase the accuracy of the CO_2 estimate. Second, data on two missing categories of fuel consumption for international bunkers – Chinese vessels fueling in China and military bunkers – are needed to properly account for all international bunkers and adjust total CO_2 emissions accordingly. Third, developing China-specific carbon sequestration coefficients through the better understanding of end-use applications for non-fuel petroleum products in China will also contribute to a more accurate CO_2 emissions inventory estimate. Ultimately, this study serves as the first step in establishing a consistent methodology for estimating China's annual energy-related CO_2 emissions and highlights possible directions for deeper understanding of the drivers behind the world's largest CO_2 emitter.

References

Anonymous, 2010, "Carbon Steel (in Chinese)." Available at: http://baike.baidu.com/view/121543.htm, accessed March 2011.

CASIS 2010. China Association of Scrap Iron and Steel, 2010, "Effective Improvement of Electric Arc Furnace Scrap Metal Recycling and Processing (in Chinese)." Available at: http://www.chinascrap.org.cn/zzwx/2010-05-18/16296.shtml

China Central Iron & Steel Research Institute (CISRI), 2011. Personal communication, 22 March 2011.

CISRI and CISA 2010. China Iron and Steel Research Institute and China Iron and Steel Association, 2010, "Energy Limit Values for the Steel Industry: National Standard and Product Application Guide (in Chinese)." Beijing: China Standards Press, June 2010.

EIA, 2008. "Documentation for Emissions of Greenhouse Gases in the United States 2006," Washington, DC: Energy Information Administration, October 2008.

Guangdong Institute of Petrochemical Chemical and Environmental Engineering, 2009, "Chemical Light Oil, Petroleum Solvents and Chemical Raw Materials (in Chinese)." Available at: http://210.38.241.2/sylzgc/new/jxzy_djjc2_003.html, accessed March 2011.

Intergovernmental Panel on Climate Change (IPCC), 1997a, "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories Reference Manual (Volume 3)."

IPCC, 1997b, "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: the Workbook (Volume 2)."

Komesaroff, M., 2008, "China's Infrastructure Boost and its Impact on 2009 Metal Demand." Presented at Access China Conference: Beijing, 12 Jan 2008.

Mysteel, 2009. "Why is the development of Electric Arc Furnace steel production in China so slow?" (in Chinese). Available at http://finance.ifeng.com/future/gypzx/20091029/1405205.shtml, accessed March 2011

National Bureau of Statistics of China (NBS), 2010a. *China Energy Statistical Yearbook 2009*. Beijing: China Statistics Press.

NBS, 2010b. *China Statistical Yearbook 2010*. Beijing: China Statistics Press.

National Development and Reform Commission of China, 2008. "YB/T 5296: Pig Iron for Steel Making (Draft Standard, in Chinese)," August 18, 2008. Available at: http://www.cmsi.org.cn/yj02/200808190057_1_0.pdf, accessed March 2011.

Sinopec, 2009. Editorial Board of the China Petrochemical Corporation Yearbook, *China Petrochemical Corporation Yearbook 2009*, Beijing: Sinopec Press, 2009

Wang, F., 2008. Wang, Fuchen, "Coal gasification technology in China: Application and Development," presentation at the China-US Clean Energy Seminary, Shanghai, China, September 2008. Available at http://chinainvestsinamerica.com/files/China-US%20Clean%20Energy%20Seminar/Coal%20Gasification%20Technology%20in%20China(en).pdf, accessed March 2011

Wang, L., 2008. "Further discussion of CO_2 emissions reduction in Chinese cement industry (in Chinese)." *China Cement* 2: 36-39.

Zhang 2010. Zhang Ying, Fushun Research Institute of Petroleum and Petrochemicals, "Innovative Hydrocracking Applications for Refinery/Petrochemical Integration," presentation at the Third K-C-J Petroleum Congress, 28 May 2010, Korea. Available at http://www.pecj.or.jp/japanese/overseas/conference/pdf/conference04-05.pdf, accessed March 2011

Appendix: Overview of the China Carbon Emissions Model

Structure of the China Carbon Emissions Model

The China Carbon Emissions Model is a macro-enabled spreadsheet model consisting of three types of worksheets: emissions results reports, data input worksheets and reference values worksheet, and calculation results worksheet. A navigation bar with shortcuts to the three types of worksheets (including drop-down for selecting the sectoral results worksheets) as well as a shortcut button to "Save & Exit" the model is included[4].

The emissions results reports have grey (colorless) tabs and include:

- Total Emissions: summary of total energy-related emissions estimated under reference and sectoral approach
- Sectoral Emissions Results: agriculture, industry, construction, transport & telecom, commerce, residential, other (public sector), thermal electricity and heat
- Non-fuel Emissions
- Carbon Sequestration

Each results worksheet include data table of major results as well as visual graphics (pie or bar chart) illustrating the results.

The "Calculation Results" worksheet has a green tab.

The data input worksheets have a light red tab and include:

- Non-fuel data inputs
- Energy Balance SCE (standard coal equivalent) table
- Energy Balance (physical) table

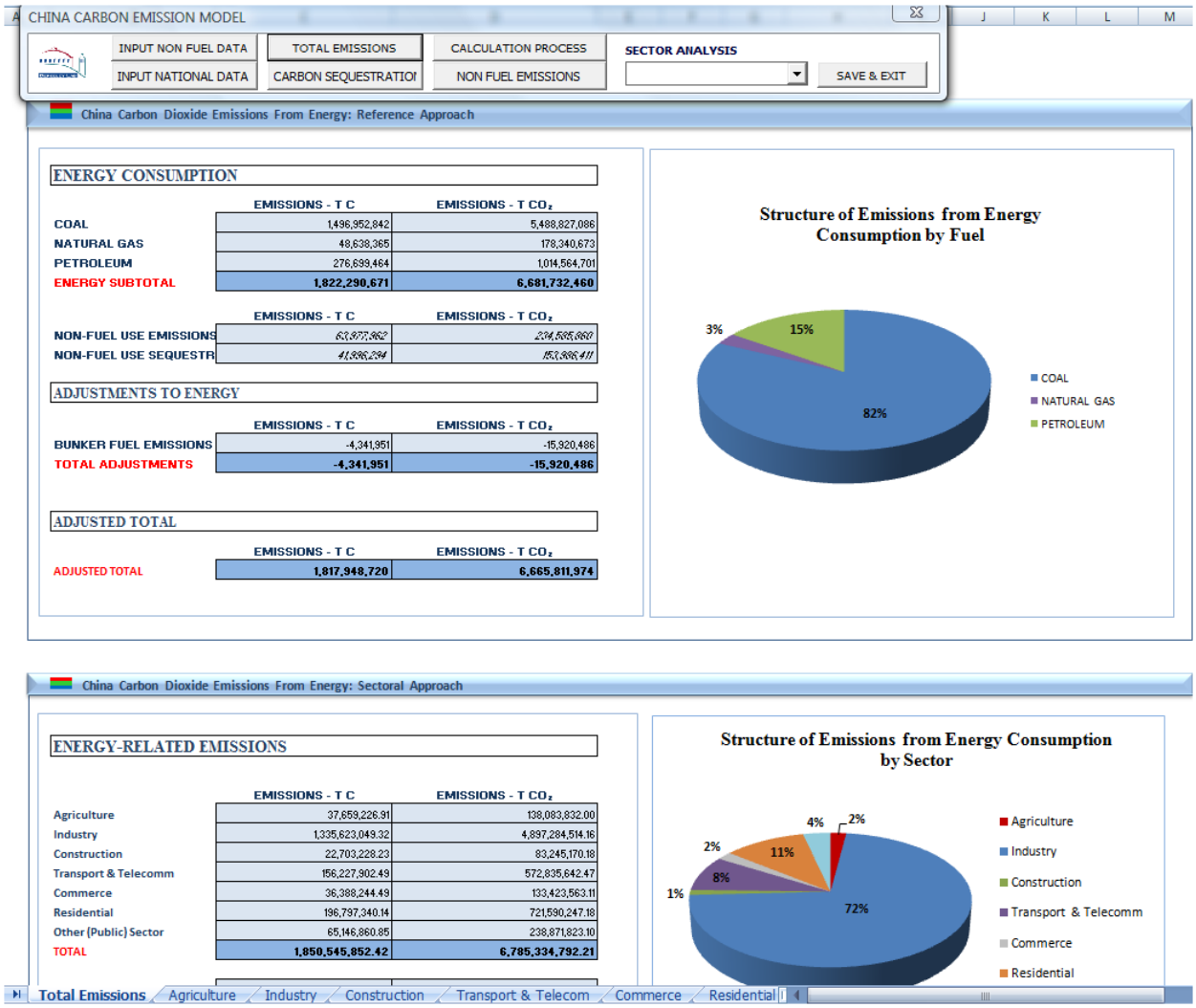
In the data input and calculations results worksheets, the legend for cell colors is:

- **Green cells:** represent data inputs from data sources
- **Blue cells:** the results of a calculation (mostly done in the Calculation Results worksheet)
- **Yellow cells:** highlight a subtotal value

There is also a "Base Data" worksheet with IPCC and EIA default values for carbon coefficients as well as the China-specific energy conversion factors from the *China Energy Statistical Yearbook*.

[4] All changes to the model are automatically saved when the "Save and Exit" button is used. If the user wishes to save the model under a different name, the "Save As" menu should be used, and the file type of "Excel Macro-Enabled Workbook (*.xlsm)" chosen in order to preserve the embodied macros.

A.1 Screenshot of China Carbon Emissions Model Total Emissions Summary



Model Data Inputs

The first data input sheet in the model for estimating China's CO_2 emissions is the "Non-fuel Use of Energy: Inputs" worksheet. This worksheet contains two sections of input data: one relating to the calculations for CO_2 sequestration in carbon steel and another relating to calculations for apparent consumption of other petroleum products not reported by NBS.

For the carbon steel inputs section, data on total crude steel production for the given year can be obtained from the annual *China Statistical Yearbook*'s table on "Output of Industrial Products" in the Industry chapter. The remaining data inputs on EAF % of Total Steel Production, Alloy Steel % of Total Steel Production and BOF % of Alloy Steel Production should be reviewed and updated based on the latest literature on Chinese steel production.

The second section on data inputs for other petroleum products uses data from Sinopec's *China Petrochemical Corporation Yearbook*.

A.2: Data Input Sheet for Non-Fuel Use of Energy

INVENTORY OF CHINESE EMISSIONS

NON-FUEL USE OF ENERGY: INPUTS

	Total Crude Steel Production (Mt)	EAF % of Total Steel	Alloy Steel % of Total Steel	BOF % of Alloy Steel
CARBON STEEL Inputs	503.06	12.60%	6.95%	92.14%

PETROLEUM PRODUCTS -MT

	Production	Imports	Exports	Apparent Consumption
Petroleum Asphalt	14.78	3.23	0.02	17.99
Lubricants	6.41	0.27	0.12	6.55
Lubricant base oil	0.00	1.37	0.13	1.24
Miscellaneous Petroleum Products				
Pentanes Plus				
Petrochemical Feedstock				
Petroleum Coke	13.80	0.92	1.80	12.92
Naphtha		0.77	1.51	-0.74
Paraffin (Waxes and Polishes)	1.52	0.03	0.62	0.93
Solvent oil (Special Naphtha)	0.99	0.04	0.00	1.02
Detergents	0.39	0.00	0.00	0.39
Chemical light oil	33.64	0.00	0.00	33.64
			Sinopec Total	73.96
			NBS Total	71.13
			Stock Change	-1.98
			Discrepancy	0.85

Non Fuel Emissions | Carbon Sequestration | Calculation Results | **Input Non-Fuel Data** | Energy balanc

In this worksheet, the dark blue and black fonts denote the petroleum product category name used by EIA while the light blue bolded font denotes the China-specific product category name.

The second data input worksheet is the annual "Energy Balance of China" table, which can be obtained from the *China Energy Statistical Yearbook* in both standard quantity (coal equivalent) units and physical units. The standard quantity energy balance table is used for the majority of calculations in estimating China's CO_2 emissions, with an adjusted Total Primary Energy Supply calculation for excluding China Airplanes & Ships Refueling Abroad and including foreign bunkers.

A.3: 2008 China Energy Balance Table (Standard Quantity)

5-26 中国能源平衡表(标准量) -2008
ENERGY BALANCE OF CHINA -2008 (STANDARD QUANTITY)

Unit: 10,000 tce					PRIMARY	SECONDARY	SECONDARY	SECONDARY	SECONDARY	SECONDARY	SECONDARY	SECONDARY
		能源合计 Energy Total		煤合计	原煤	洗精煤	其他洗煤	型煤	焦炭	焦炉煤气	其他煤气	其他焦化产品
		(发电煤耗	(电热当量									
项 目	Item	计算法)	计算法)				Other					Other
		(coal equivalent	(calorific value	Coal Total	Raw Coal	Cleaned	Washed	Briquettes	Coke	Coke Oven	Other Gas	Coking
		calculation)	calculation)			Coal	Coal			Gas		Products
	(Adjusted Calculation: Excludes Bunkers in row 17)											
一. 可供本地区消费的能源量	Total Primary Energy Supply	**287,011.28**	**273,079.23**	**196,401.74**	**196,250.85**	**231.02**	**(71.14)**	**(8.99)**	**(2,253.58)**			**33.34**
1. 一次能源生产量	Indigenous Production	260,551.54	246,350.88	200,146.86	200,146.86							
水电	Hydro Power	19,470.31	7,191.95	201,024.19								
核电	Nuclear Power	2,275.60	840.56	196,401.74								
2. 回收能	Recovery of Energy	6,510.84	6,510.84									
3. [illegible]	Import	35,977.34	35,896.72	2,946.16	2,154.86	617.15	174.14	0.02				139.67
4. [illegible]	*China Airplanes&Ships Refueling in Abroad*	*786.51*	*786.51*									
5. [illegible]	Export (-)	(9,230.99)	(8,881.76)	(3,456.81)	(3,135.64)	(311.09)	(1.20)	(8.89)	(1,186.40)			(106.33)
6. [illegible] -)	Foreign Airplanes&ships Refueling in China	(723.62)	(723.62)			-						
7. 库存增(-)、减(+)量	Stock Change	(6,860.33)	(6,860.33)	(3,234.48)	(2,915.24)	(75.04)	(244.08)	(0.13)	(1,067.18)			
二. 加工转换投入(-)产出(+)量	Input(-) & Output(+) of Transformation	**(5,166.01)**	**(67,071.12)**	**(140,581.68)**	**(147,039.13)**	**1,863.82**	**3,999.64**	**593.99**	**31,207.51**	**3,235.61**	**61.99**	**771.96**
1. 火力发电	Thermal Power	(0.00)	(58,541.24)	(89,701.86)	(88,203.08)	(23.53)	(1,475.25)			(548.14)	(290.04)	
2. 供 热	Heating Supply	(0.00)	(3,363.86)	(10,873.51)	(10,613.96)	(5.86)	(253.70)			(78.82)	(109.71)	
3. 洗 选 煤	Coal Washing	(2,502.81)	(2,502.81)	(2,502.81)	(43,442.79)	34,646.61	6,293.37					
4. 炼 焦	Coking	(819.06)	(819.06)	(36,457.95)	(4,231.75)	(32,177.47)	(48.73)		31,115.40	3,766.36	15.99	741.14
5. 炼 油	Petroleum Refineries	(1,380.18)	(1,380.18)									
6. 制 气	Gas Works	(235.41)	(235.41)	(1,004.65)	(428.72)	(575.93)			274.36	96.20	445.75	36.22
#焦炭再投入量(-)	Coke Input (-)	(187.65)	(187.65)						(182.25)			(5.40)
7. 煤制品加工	Briquettes	(40.89)	(40.89)	(40.89)	(118.83)		(516.05)	593.99				
三. 损 失 量	Loss	**7,736.14**	**3,209.10**									
四. 终端消费量	Total Final Consumption	**278,546.14**	**207,234.95**	**60,442.51**	**53,812.12**	**2,115.09**	**3,928.75**	**586.55**	**28,862.83**	**3,213.99**	**5,583.54**	**803.13**
1. 农、林、牧、渔、水利业	Farming, Forestry, Animal Husbandry, Fishery & Water Conservanc	6,013.13	4,150.86	1,158.67	1,143.55		15.13		51.62			
2. 工 业	Industry	196,832.49	145,707.08	48,929.32	43,297.62	2,100.15	3,344.22	187.33	28,723.40	2,940.41	5,147.97	803.13
#用作原料、材料	Non-Energy Use	10,745.81	10,745.81	3,131.25	2,874.96	107.95	140.46	7.89	1,148.94	29.40		184.72
3. 建 筑 业	Construction	3,812.53	3,035.33	460.12	454.13	1.80	4.19		10.39			
4. 交通运输、仓储及邮电通讯业	Transport, Storage, Postal & Telecommunications Services	22,484.75	21,261.26	507.78	486.79	13.14	7.84		0.28		0.81	
5. 批发和零售贸易业、餐饮业	Wholesale, Retail Trade and Catering Service	5,733.58	3,554.32	1,362.59	1,338.08		12.23	12.28	7.32	6.82	25.71	
6. 生活消费	Residential Consumption	31,898.32	21,855.35	6,684.45	5,823.90		477.74	382.81	63.07	255.75	409.05	
城 镇	Urban	19,615.20	13,430.43	1,752.99	1,456.75		170.78	125.45	41.14	255.75	404.93	
乡 村	Rural	12,283.12	8,424.92	4,931.46	4,367.15		306.96	257.35	21.94		4.11	
7. 其他	Other	11,771.34	7,670.74	1,339.60	1,268.05		67.40	4.14	6.73	11.01		
五. 平衡差额	Statistical Difference	**(4,437.01)**	**(4,435.93)**	**(4,622.46)**	**(4,600.41)**	**(20.25)**	**(0.25)**	**(1.56)**	**91.10**	**21.62**	**(0.01)**	**2.18**
六. 消费量合计	Total Final Consumption	**291,448.30**	**277,515.17**		**200,851.25**							

Fridley, David: Excluded from calculations; not a standard component of IPCC bunkers calculations

2008 China Energy Balance Table (continued)

5-26 中国能源平衡表（标准量）-2008
ENERGY BALANCE OF CHINA -2008 (STANDARD QUANTITY)

Unit: 10,000 tce

Fridley, David: Calculation excluding bunkers in row 17

Fridley, David: Excluded from calculations; not a standard component of IPCC bunkers calculations

项 目	Item	油品合计 Petroleum Products Total	PRIMARY 原油 Crude Oil	SECONDARY 汽油 Gasoline	SECONDARY 煤油 Kerosene	SECONDARY 柴油 Diesel Oil	SECONDARY 燃料油 Fuel Oil	SECONDARY 液化石油气 LPG	SECONDARY 炼厂干气 Refinery Gas	SECONDARY 其他石油制品 Other Petroleum Products	PRIMARY 天然气 Natural Gas	热力 Heat	电力 Electricity	(10 000 tce) 其他能源 Other Energy
	(Adjusted Calculation: Excludes Bunkers in row 17)				416.00	258.61	2,524.97							
一. 可供本地区消费的能源量	Total Primary Energy Supply	**53,365.67**	**50,713.31**	**(293.61)**	**193.52**	**195.25**	**2,150.07**	**341.97**		**65.16**	**10,860.65**		**8,160.58**	**989.30**
1. 一次能源生产量	Indigenous Production	27,206.20	27,206.20								10,679.90		8,317.92	
水电	Hydro Power												7,191.95	
核电	Nuclear Power										10,812.03		840.56	
2. 回收能	Recovery of Energy													989.30
3. [illegible]	Import	32,151.34	25,555.54	292.35	953.16	909.89	3,123.03	444.42		872.95	612.33		47.22	
4. 国	*China Airplanes&Ships Refueling in Abroad*	*786.51*			*278.09*	*12.55*	*495.87*							
5. [illegible]	Export (-)	(3,496.08)	(605.37)	(299.21)	(789.32)	(91.87)	(1,045.25)	(116.32)		(548.75)	(431.59)		(204.55)	
6. [illegible] -)	Foreign Airplanes&ships Refueling in China	(723.62)			(250.29)	(37.96)	(435.38)							
7. 库存增 (-)、减 (+)量	Stock Change	(2,558.67)	(1,443.06)	(286.76)	1.87	(597.35)	11.80	13.88		(259.04)	1,455.22			
二. 加工转换投入 (-)产出 (+)量	Input(-) & Output(+) of Transformation	**(2,871.11)**	**(48,722.61)**	**9,339.05**	**1,705.21**	**19,268.72**	**1,797.25**	**3,271.90**	**1,391.76**	**9,077.62**	**(1,455.22)**	**8,789.72**	**34,290.06**	**(519.96)**
1. 火力发电	Thermal Power	(888.62)	(12.67)	(0.18)		(269.75)	(496.48)		(56.08)	(53.45)	(1,090.20)		34,290.06	(312.45)
2. 供 热	Heating Supply	(605.80)	(1.36)	(0.01)			(185.42)	(10.61)	(274.46)	(133.94)	(284.62)	8,789.72		(201.12)
3. 洗 选 煤	Coal Washing													
4. 炼 焦	Coking													
5. 炼 油	Petroleum Refineries	(1,373.79)	(48,708.58)	9,339.24	1,705.21	19,538.47	2,482.05	3,282.51	1,722.30	9,265.01				(6.39)
6. 制 气	Gas Works	(2.90)					(2.90)				(80.39)			
#焦炭再投入量 (-)	Coke Input (-)													
7. 煤制品加工	Briquettes													
三. 损 失 量	Loss	**289.65**	**286.22**					**3.43**			**183.94**	**108.06**	**2,627.45**	
四. 终端消费量	Total Final Consumption	**50,183.74**	**1,703.96**	**9,042.33**	**1,904.00**	***19,448.59***	**3,939.78**	**3,618.42**	**1,390.63**	**9,136.03**	**9,172.87**	**8,681.47**	**39,823.86**	**467.01**
1. 农、林、牧、渔、水利业	Farming, Forestry, Animal Husbandry, Fishery & Water Conservanc	1,847.59		236.07	1.85	1,601.17	2.14	6.35				2.78	1,090.18	
2. 工 业	Industry	18,461.33	1,703.96	862.21	72.22	3,397.80	2,228.77	845.46	1,390.63	7,960.28	5,542.78	6,116.57	28,575.17	467.01
#用作原料、材料	Non-Energy Use	4,825.78	226.63	27.68	8.42	64.22	108.02	92.24	11.96	4,286.61	1,385.69			40.02
3. 建 筑 业	Construction	2,083.35		288.67	14.23	540.28	53.86	10.56		1,175.75	13.17	16.85	451.46	
4. 交通运输、仓储及邮电通讯业	Transport, Storage, Postal & Telecommunications Services	19,147.66		4,547.26	1,728.29	11,145.81	1,632.56	93.74			840.03	61.94	702.77	
5. 批发和零售贸易业、餐饮业	Wholesale, Retail Trade and Catering Service	549.17		199.05	30.63	222.53	8.93	88.03			236.08	116.20	1,250.43	
6. 生活消费	Residential Consumption	4,637.31		1,258.26	18.66	862.71		2,497.68			2,262.63	2,140.29	5,402.81	
城 镇	Urban	3,437.83		895.54	2.53	640.15		1,899.61			2,254.60	2,140.29	3,142.90	
乡 村	Rural	1,199.48		362.72	16.13	222.57		598.07			8.02		2,259.91	
7. 其他	Other	3,457.33		1,650.81	38.11	1,678.29	13.52	76.59			278.20	226.84	2,351.04	
五. 平衡差额	Statistical Difference	**21.17**	**0.52**	**3.11**	**(5.27)**	***15.37***	**7.54**	**(7.98)**	**1.13**	**6.74**	**48.62**	**0.19**	**(0.68)**	**2.33**
六. 消费量合计	Total Final Consumption													

The energy balance table in physical units is primarily included as a reference and used to calculate the energy conversion factor for other coal gas.

Model Calculations

The underlying calculations behind all of the results analysis is laid out in the "Calculations Results" worksheet, which is divided into four main sections. Table 1 and its corresponding sub-tables include all of the calculations for primary and secondary energy-related emissions by fuel under the reference approach. It also includes a summary table of all emissions from energy consumption, non-fuel emissions, non-fuel sequestration, and the bunker adjustment.

A.4: Calculation Results Worksheet

CHINA CARBON EMISSION MODEL

INPUT NON FUEL DATA | TOTAL EMISSIONS | CALCULATION PROCESS | SECTOR ANALYSIS
INPUT NATIONAL DATA | CARBON SEQUESTRATIOI | NON FUEL EMISSIONS | SAVE & EXIT

Table 1: Total Energy-Related Emissions

Table 1.1: Primary Energy Emissions

	10^4tce	Tce	TJ	Tons of Carbon	Total Carbon Emissions (tons)	Total CO2 Emissions (tons)
Raw Coal	200,851.25	2,008,512,510.26	58,790,395.58	1,516,792,206.03	1,516,792,206.03	5,561,571,422.10
Natural gas	10,860.65	108,606,470.00	3,178,978.13	48,638,365.31	48,638,365.31	178,340,672.82
Crude Petroleum	50,713.31	507,133,073.89	14,844,096.75	296,881,935.01	296,881,935.01	1,088,567,095.03
Subtotal	262,425.21	2,624,252,054.15	76,813,470.46	1,862,312,506.35	1,862,312,506.35	6,828,479,189.95

Table 1.2: Secondary Energy Emissions

	10^4tce	Tce	TJ	Tons of Carbon	Total Carbon Emissions (tons)	Total CO2 Emissions (tons)
Cleaned Coal	231.02	2,310,203.25	67,621.07	1,744,623.58	1,744,623.58	6,396,953.12
Washed Coal	-71.14	-711,379.83	-20,822.52	-537,221.14	-537,221.14	-1,969,810.84
Briquettes	-8.99	-89,926.32	-2,632.20	-67,910.73	-67,910.73	-249,005.99
Coke	-2,253.58	-22,535,800.02	-659,636.72	-19,459,283.15	-19,459,283.15	-71,350,704.87
Coke Oven Gas	0.00	0.00	0.00	0.00	0.00	0.00
Other Gas	0.00	0.00	0.00	0.00	0.00	0.00
Other Coking Products	33.34	333,390.60	9,758.55	287,877.16	287,877.16	1,055,549.58
Secondary energy -Coal Subtotal	-2,069.35	-20,693,512.32	-605,711.82	-18,031,914.27	-18,031,914.27	-66,117,019.00
Gasoline	-293.61	-2,936,099.24	-85,941.43	-1,624,293.02	-1,624,293.02	-5,955,741.06
Kerosene	416.00	4,159,999.62	121,765.75	2,374,432.04	2,374,432.04	8,706,250.80
Diesel Oil	258.61	2,586,146.74	75,698.10	1,529,101.71	1,529,101.71	5,606,706.27
Fuel Oil	2,524.97	25,249,656.98	739,072.98	15,594,439.84	15,594,439.84	57,179,612.73
LPG	341.97	3,419,713.07	100,097.10	1,721,670.18	1,721,670.18	6,312,790.64
Other Petroleum Products	65.16	651,605.23	19,072.89	411,022.18	411,022.18	1,507,081.33
Secondary energy -Petroleum Subtotal	3,313.10	33,131,022.40	969,765.39	20,006,372.93	20,006,372.93	73,356,700.73

Table 1.3: Bunker Fuel Emissions

	10^4tce	Tce	TJ	Tons of Carbon	Total Carbon Emissions (tons)	Total CO2 Emissions (tons)
Kerosene	-250.29	-2,502,851.40	-73,260.00	-1,428,569.97	-1,428,569.97	-5,238,089.91
Diesel Oil	-37.96	-379,574.55	-11,110.38	-224,429.68	-224,429.68	-822,908.84
Fuel Oil	-435.38	-4,353,801.36	-127,438.44	-2,688,951.12	-2,688,951.12	-9,859,487.43
Bunker Fuel Subtotal	-723.62	-7,236,227.31	-211,808.82	-4,341,950.78	-4,341,950.78	-15,920,486.18

Table 1.4: Total Energy Emissions

Energy Consumption	Tce	TJ	Total Carbon Emissions (tons)	Total CO2 Emissions (tons)	% of Total Emissions
Coal	1,987,818,997.94	58,184,683.76	1,496,952,841.67	5,488,827,086.12	
Natural gas	108,606,470.00	3,178,978.13	48,638,365.31	178,340,672.82	
Petroleum	540,264,096.28	15,813,862.14	276,699,464.01	1,014,564,701.36	
Energy Subtotal	2,636,689,564.23	77,177,524.02	1,822,290,670.99	6,681,732,460.30	6,835,718,871.68
Nonfuel Use Emission			63,977,961.90	234,585,860.31	3.52%
Nonfuel Use Sequestration			41,996,294.01	153,986,411.38	2.25%
Bunker Fuel			-4,341,950.78	-15,920,486.18	
Total			1,817,948,720.21	6,665,811,974.12	

nzheng:
Total Carbon = energy consumption emissions + non-energy emissions + CO2 sequestration

Non Fuel Emissions | Carbon Sequestration | Calculation Results | Input Non-Fuel Data | Energy balance SCE | 2008 energy balance (physical)

Table 2 and the subsequent sub-tables in this section focus on calculating carbon emissions and sequestration from the non-energy use of fuels, including carbon steel sequestration, non-energy emissions and sequestration of petroleum products, and emissions from non-energy use of natural gas. The purple sidebar includes an additional side calculation estimating EAF carbon steel which is not included in the final results.

Table 2.1: Non Energy use Coal

	Carbon Steel Production Parameters	C Ton Sequestration	CO2 Ton Sequestration	Source
Total Crude Steel Production	503,057,500.00	611,186.72	2,241,017.36	*National Bureau of Statistics, 2010.*
Primary Steel Production (BOF method)	439,672,255.00	0.041%		
Alloy Steel Share of Total Steel	6.95%			*China Association of Scrap Iron and Steel, 2010.*
BOF Alloy Steel Share of Alloy Steel	92%			*China Central Iron & Steel Research Institute, 2011*
EAF Steel Share of Total Steel Production	12.6%			*China Association of Scrap Iron and Steel, 2010.*
BOF Carbon Steel Share of Total Steel	81.0%			
% Product Steel	50%			*Komesaroff, 2008*
Average carbon content product steel	0.2%			*Anonymous, 2010, "Carbon Steel" on Baidu Website (In Chinese).*
% Structural Steel	50%			*Komesaroff, 2008*
Average carbon content structural steel	0.1%			*Anonymous, 2010, "Carbon Steel" on Baidu Website (In Chinese).*
Avg Carbon Content	0.150%			

EAF Carbon Steel Calculation

	tonnes
Total Alloy Steel Production	34,962,496
EAF Alloy Steel Production	2,748,052
EAF Steel Production	63,385,245
EAF Carbon Steel Production	60,637,193
EAF Carbon Steel Pig Iron Use	16,675,228
New Sequestered Carbon	25,013
Share of Total Sequestered Carb-	0.06%

	10^4 toe	Toe	TJ	C ton	C Ton Sequestration	Total Carbon Emissions (tons)	Total CO2 Emissions (tons)	Sequestration Coefficient	Reference
Raw Coal	2,874.36	28,743,620.47	841,519.06	21,711,191.75	0.00	21,711,191.75	79,607,703.10	0.00	Page 27
Cleaned Coal	107.95	1,079,476.04	31,596.93	815,200.72	0.00	815,200.72	2,988,069.29	0.00	Page 27
Washed Coal	140.46	1,404,572.46	41,112.70	1,060,707.63	0.00	1,060,707.63	3,888,261.32	0.00	Page 27
Briquettes	7.89	78,864.18	2,308.40	59,556.79	0.00	59,556.79	218,374.31	0.00	Page 27
Coke	1,148.94	11,489,361.61	336,300.68	9,920,869.93	0.00	9,920,869.93	36,376,523.08	0.00	Page 27
Coke Oven Gas	29.40	294,040.84	8,606.76	111,887.83	0.00	111,887.83	410,255.37	0.00	Page 27
Other Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Page 27
Other Coking Products	184.72	1,847,190.43	54,068.40	1,595,017.83	1,196,263.37	398,754.46	1,462,099.67	0.75	Page 27
				Subtotal	1,196,263.37	34,078,169.12	124,953,286.76		

Total Non Energy use Coal	C Ton Sequestration	C Ton Emission	questration % Total Carbon	Nonfuel Emissions % Total Emissions
	1,807,450.09	34,078,169.12	0.12%	2.28%

Table 2.2 : Non Energy use - Petroleum

	10^4 Toe	Toe	TJ	C Ton	C Ton Sequestration	Total Carbon Emissions (tons)	Total CO2 Sequestered	Sequestration Coefficient	Reference
Gasoline	27.68	276,769.72	8,101.22	153,113.06	76,556.53	76,556.53	280,707.27	0.50	Page 12
Kerosene	8.42	84,204.22	2,464.71	48,061.83	24,030.92	24,030.92	88,113.36	0.50	Page 12
Diesel Oil	64.22	642,183.62	18,797.11	373,701.61	186,850.80	186,850.80	685,119.61	0.50	Page 12
Fuel Oil	108.02	1,080,220.16	31,618.71	667,154.74	333,577.37	333,577.37	1,223,117.02	0.50	Page 12
LPG	92.24	922,395.20	26,999.07	464.38	371.51	92.88	1,362.19	0.80	Page 13
Still Gas	11.96	119,593.85	3,500.59	60.21	48.17	12.04	176.62	0.80	Page 23
				Subtotal	624,435.29	624,120.53	2,289,596.07		

	MT	Ton	TJ	C Ton	C Ton Sequestration	Total Carbon Emissions (tons)	Total CO2 Sequestered	Sequestration Coefficient	Reference
Petroleum asphalt	17.39	17,387,700.00	629,569.50	13,850,529.00	13,850,529.00	0.00	50,785,273.00	1.00	Page 10
lubricants	6.55	6,550,200.00	273,303.16	5,478,063.26	2,739,031.63	2,739,031.63	10,043,115.38	0.50	Page 18
Lubricant base oil	1.24	1,241,800.00	51,927.11	1,038,542.18	519,271.09	519,271.09	1,903,993.99	0.50	Page 18
Miscellaneous petroleum products	0.00	0.00			0.00	0.00	0.00	1.00	Page 18
Pentanes plus	0.00	0.00			0.00	0.00	0.00	0.00	Page 19
Petrochemical Feedstock (Chem Light Oil + Naphtha)	0.00	0.00			0.00	0.00	0.00	0.75	Page 20
Petroleum coke	12.92	12,922,500.00	439,365.00	12,082,537.50	0.00	12,082,537.50	0.00	0.00	Page 21
Naphtha	-0.74	-741,000.00	-31,722.21	-634,444.20	0.00	-634,444.20	0.00	0.00	Page 23
Paraffin (Waxes and Polishes)	0.33	334,600.00	40,187.80	754,616.42	754,616.42	0.00	2,766,326.86	1.00	Page 25
Solvent oil (Special Naphtha)	1.02	1,023,300.00	42,730.31	855,806.26	0.00	855,806.26	0.00	0.00	Page 20
Detergents	0.33	331,600.00	13,706.00	274,120.00	0.00	274,120.00	0.00	0.00	Page 20
Chemical light oil	33.64	33,644,300.00	1,446,730.70	28,934,614.00	21,700,960.50	7,233,653.50	79,570,188.50	0.75	Page 20
Subtotal	73.36	73,955,600.00	2,906,457.37	62,634,384.41	39,564,408.64	23,069,975.78	145,069,498.33		
Reference Report: Documentation for Emissions of Greenhouse Gases in the	United States 2006			21.53					

Total Non Energy use Petroleum	C Ton Sequestration	C Ton Emission	questration % Total Carbon	Nonfuel Emissions % Total Emissions
	40,188,843.93	23,634,096.31	12.1%	8.6%

Fridley, David: (Petroleum Non-Fuel Sequestration / (Energy Petroleum Emissions + Nonfuel Petroleum Emissions + Nonfuel Petroleum Sequestration)

Fridley, David: Average Carbon Content of "Other Petroleum Products"

Fridley, David: No data on non-fuel use of petroleum coke

Table 2.2.1 : Non Energy use- Petroleum- Emissions and Sequestration

% Product Emitted	36.8%	23,069,975.78
% Product Sequestered	63.2%	39,564,408.64

Table 2.3: Non Energy use- Natural Gas

	10^4 Toe	Toe	TJ	Tons of Carbon	Tons of Stored Carbon	Tons of Carbon Emitted	Tons of Stored CO_2	Storage Coefficient	Reference
Natural Gas Flaring	n/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Page 28
Non-Energy Use	1,385.69	13,856,937.50	405,601.08	6,205,696.48	0.00	6,205,696.48	0.00	0.00	Page 26
Subtotal				6,205,696.48	0.00	6,205,696.48	0.00		
Reference Report: Documentation for Emissions of Greenhouse Gases in the	United States 2006				Nonfuel Emissions % Total Emissions:	12.8%			

Carbon Sequestration | Calculation Results | Input Non-Fuel Data | Energy balance SCE | 2008 energy balance (physical) | Base Data | Sources | Sheet1

Table 3 marks the beginning of calculations for the sectoral approach of estimating China's CO_2 emissions and includes four sets of tables:

- fuel consumption by sector in original reported units of 10,000 tce
- fuel consumption by sector in converted units of tce
- fuel consumption by sector in converted units of TJ
- carbon emissions by sector and fuel
- CO_2 emissions by sector and fuel

	A	G	H	I	J	K	L	M	N	O	P	Q	R
115	Table 3 : Emissions from Sector Energy Consumption												
116													
117	Sector- Unit 10⁴tce	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Other Petroleum Products	Natural Gas	Heat	Electricity	
118	Agriculture	0.00	236.07	1.65	1,601.17	2.14	5.35	0.00	0.00	0.00	2.78	1,090.18	
119	Industry	1,703.96	862.21	72.22	3,397.80	2,228.17	845.46	1,390.63	7,360.28	5,542.78	5,116.57	28,515.17	
120	Non-energy use	226.63	27.68	8.42	64.22	108.02	92.24	11.96	4,286.61	1,385.69			
121	Construction	0.00	288.67	14.23	540.28	53.86	10.56	0.00	1,175.75	13.17	16.85	451.46	
122	Transport & Telecom	0.00	4,547.26	1,726.29	11,145.81	1,632.56	93.74	0.00	0.00	840.03	61.94	702.77	
123	Commerce	0.00	193.05	30.63	222.53	8.33	88.03	0.00	0.00	236.08	116.20	1,250.43	
124	Residential	0.00	1,258.26	16.66	862.71	0.00	2,437.68	0.00	0.00	2,262.63	2,140.23	5,402.81	
125	Other (Public Sector)	0.00	1,650.81	38.11	1,676.29	13.52	76.59	0.00	0.00	278.20	226.84	2,351.04	
126	Thermal Electricity	12.67	0.18	0.00	269.75	436.48	0.00	56.08	53.45	1,030.20	0.00	0.00	
127	Heat Supply	1.36	0.01	0.00	0.00	185.42	10.61	274.46	133.34	284.62	0.00	0.00	
128													
129	*Sector- Unit tce*	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Other Petroleum Products	Natural Gas	Heat	Electricity	
130	Agriculture	0	0	18,540	16,011,636	21,429	63,547	0	0	0	27,842	10,901,845	
131	Industry	17,039,626	276,770	722,163	33,977,969	22,287,731	8,454,585	13,906,261	79,602,830	55,427,750	61,165,685	285,751,718	
132	Construction	0	0	142,284	5,402,781	538,582	105,601	0	11,757,483	131,670	168,468	4,514,609	
133	Transport & Telecom	0	30,146,512	17,282,917	111,458,096	16,325,612	937,379	0	0	8,400,280	619,371	7,027,668	
134	Commerce	0	0	306,345	2,225,283	83,288	880,233	0	0	2,360,750	1,162,015	12,504,338	
135	Residential	0	0	186,587	8,627,146	0	24,376,838	0	0	22,626,275	21,402,310	54,028,069	
136	Other (Public Sector)	0	0	381,149	16,782,932	135,157	765,949	0	0	2,781,936	2,268,369	23,510,401	
137	Thermal Electricity	126,717	0	0	2,697,533	4,364,814	0	560,833	534,544	10,302,010	0	0	
138	Heat Supply	13,572	0	0	0	1,854,180	106,115	2,744,607	1,333,375	2,846,200	0	0	
139													
140													
141	*Sector - Unit: TJ*	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Other Petroleum Products	Natural Gas	Heat	Electricity	
142	Agriculture	0.00	0.00	542.67	468,672.19	627.24	1,860.05	0.00	0.00	0.00	814.95	319,103.63	
143	Industry	498,760.34	8,101.22	21,138.16	994,556.04	652,375.60	247,470.89	407,044.82	2,330,023.76	1,622,404.31	1,790,357.19	8,364,128.39	
144	Construction	0.00	0.00	4,164.75	158,142.72	15,764.63	3,091.00	0.00	344,148.75	3,854.06	4,931.75	132,145.37	
145	Transport & Telecom	0.00	2,638,643.80	505,861.61	3,262,446.37	477,860.70	27,437.67	0.00	0.00	245,881.36	18,123.37	205,704.16	
146	Commerce	0.00	0.00	8,966.32	65,135.40	2,613.50	25,766.72	0.00	0.00	69,100.60	34,012.89	366,003.65	
147	Residential	0.00	0.00	5,461.53	252,521.88	0.00	731,087.40	0.00	0.00	662,284.36	626,476.33	1,581,434.78	
148	Other (Public Sector)	0.00	0.00	11,156.45	491,246.72	3,956.13	22,413.80	0.00	0.00	81,430.72	66,396.54	688,163.30	
149	Thermal Electricity	3,709.08	0.00	0.00	78,958.44	145,323.14	0.00	16,415.92	15,646.44	319,108.53	0.00	0.00	
150	Heat Supply	397.25	0.00	0.00	0.00	54,272.99	3,106.06	80,336.34	39,204.34	83,310.02	0.00	0.00	
151										**Subtotal**	2,541,119.02	11,656,689.93	
152													
153	*Sector - Unit: tons of carbon emissions*	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Other Petroleum Products	Natural Gas	Heat	Electricity	Subtotal
154	Agriculture	-	-	10,582	9,467,178	13,235	31,993	-		-	28,100	18,912,271	37,659,226.91
155	Industry	9,875,207	153,113	412,194	20,090,032	13,765,125	4,256,499	7,408,216	50,212,195	24,822,786	61,733,305	495,715,559	1,343,783,882.37
156	Construction	-	-	81,213	3,194,483	332,634	53,165	-	7,416,432	58,967	170,052	7,831,640	22,703,228.23
157	Transport & Telecom	-	49,870,368	9,864,681	65,901,429	10,082,861	471,928	-	-	3,761,985	625,119	12,181,438	156,603,954.18
158	Commerce	-	-	174,855	1,315,735	55,145	443,188	-	-	1,057,233	1,172,798	21,632,240	36,388,244.43
159	Residential	-	-	106,500	5,100,942	-	12,574,703	-	-	10,132,960	21,601,530	93,726,661	136,737,340.14
160	Other (Public Sector)	-	-	217,551	9,923,184	83,474	385,621	-	-	1,245,830	2,289,419	40,785,308	55,146,860.85
161	Thermal Electricity	74,182	-	-	1,594,961	3,066,318	-	295,770	337,182	4,882,361			630,855,316.36
162	Heat Supply	7,945	-	-	-	1,145,160	53,424	1,462,121	844,857	1,274,643			87,620,322.62
163										**Subtotal**	87,620,322.62	630,855,316.36	1,859,088,737.16
164													
165	*Sector - Unit: tons of CO_2 ; emissions*	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Other Petroleum Products	Natural Gas	Heat	Electricity	Subtotal
166	Agriculture	-	-	38,801	34,712,987	48,527	117,307	-		-	103,034	69,344,394	138,083,832
167	Industry	36,575,758	561,415	1,511,378	73,663,451	50,472,125	15,607,164	27,163,458	184,111,381	91,016,882	226,355,451	1,817,623,717	4,927,207,563
168	Construction	-	-	297,780	11,713,104	1,219,657	194,939	-	27,193,586	216,213	623,523	28,716,747	83,245,170
169	Transport & Telecom	-	182,858,015	36,170,535	241,638,572	36,970,490	1,730,402	-	-	13,793,344	2,292,102	44,701,938	574,236,493
170	Commerce	-	-	641,135	4,824,362	202,198	1,625,021	-	-	3,876,544	4,300,261	79,538,212	133,423,563
171	Residential	-	-	390,499	18,703,454	-	46,107,246	-	-	37,154,186	79,205,609	343,664,425	721,530,247
172	Other (Public Sector)	-	-	797,686	36,385,007	306,072	1,413,942	-	-	4,568,263	8,394,537	149,546,128	238,811,623
173	Thermal Electricity	271,999	-	-	5,848,189	11,243,167	-	1,085,489	1,236,334	17,901,989			2,533,136,160
174	Heat Supply	29,132	-	-	-	4,198,920	195,889	5,361,112	3,097,808	4,673,692			321,274,517
175										**Subtotal**	321,274,517.01	2,533,136,159.97	6,816,658,702.92

Note: not all fuels are shown in this screenshot due to the table width. For thermal electricity and heat, the total energy input is summed across the fuel columns in the two energy unit tables and then redistributed to the sectors based on their relative proportion of final electricity and heat demand in the electricity and heat columns in the emissions tables.

Table 4 and sub-tables presents the data and calculations for estimating the adjustments to sectoral energy consumption, including other transformation sector losses (attributed to industry), international bunkers (attributed to transport) and China Airplanes and Ships Refueling Abroad (deducted from transport).

Table 4: Emissions Adjustments to Sector Energy Consumption

Table 4.1 Emissions from Other Transformation Sector Losses

	Primary Fuel Loss Type	10^4tce	Tce	TJ	Tons of Carbon	Total C Emissions	Total CO2 Emissions
Coal Washing	Coal	2,502.81	25,028,148	732,589	18,900,803	18,900,803	69,302,944
Coking	Coal	819.06	8,190,641	239,745	6,185,424	6,185,424	22,679,887
Petroleum Refineries	Oil	1,380.18	13,801,826	403,988	8,079,758	8,079,758	29,625,781
Gas Works	Coal	47.76	477,602	13,980	360,676	360,676	1,322,480
Briquettes	Coal	40.89	408,907	11,969	308,799	308,799	1,132,265
					Subtotal	33,835,461	124,063,357

Table 4.2 Emissions from International Bunkers (Foreign Ships and Planes Refueling in China)

	10^4tce	Tce	TJ	C ton	Total C Emissions	Total CO2 Emissions
Kerosene	250.29	2,502,851	73,260	1,428,570	1,428,570	5,238,090
Diesel Oil	37.96	379,575	11,110	224,430	224,430	822,909
Fuel Oil	435.38	4,353,801	127,438	2,688,951	2,688,951	9,859,487
				Subtotal	4,341,951	15,920,486

Table 4.3 Emissions from Chinese Airplanes and Ships Refueling Abroad

	10^4tce	Tce	TJ	C ton	Total C Emissions	Total CO2 Emissions
Kerosene	(278.09)	(2,780,946)	(81,400)	(1,587,300)	(1,587,300)	(5,820,100)
Diesel Oil	(12.55)	(125,456)	(3,672)	(74,178)	(74,178)	(271,986)
Fuel Oil	(495.87)	(4,958,671)	(145,143)	(3,062,524)	(3,062,524)	(11,229,256)
				Subtotal	(4,724,002)	(17,321,342)

Table 5 shows the adjusted total emissions from sectoral energy consumption in terms of carbon and CO_2 emissions. The "Adjusted Subtotal" column includes the bunker adjustments to the transport sector and the gasoline reallocation adjustment (all except industrial non-energy use reallocated to transport sector). The Total Carbon/CO_2 Emissions column in yellow includes an additional adjustment for allocating Other Transformation Losses to industry and represents the adjusted sectoral total emissions reported in the results worksheets.

Table 5: Adjusted Total Emissions from Sector Energy

Sector - Unit: tons of carbon emissions	Fuel Oil	LPG	Refinery Gas	Other Petroleum Products	Natural Gas	Heat	Electricity	Adjusted S	tion Losses	Total Carbon Emissions
Agriculture	13,235	31,993	-	-	-	28,100	18,912,271	37,65		37,659,226.91
Industry	13,431,548	4,256,128	7,408,168	10,647,786	24,822,786	61,733,305	495,715,559	1,301,78	33,835,460.96	1,335,623,049.32
Construction	332,634	53,165	-	7,416,432	58,967	170,052	7,831,840	22,703,228.23		22,703,228.23
Transport & Telecom	9,709,288	471,928	-	-	3,761,985	625,119	12,191,438	156,227,902.49		156,227,902.49
Commerce	55,145	443,188	-	-	1,057,239	1,172,798	21,692,240	36,388,244.49		36,388,244.49
Residential	-	12,574,703	-	-	10,132,960	21,601,530	93,726,661	196,797,340.14		196,797,340.14
Other (Public Sector)	83,474	385,621	-	-	1,245,890	2,289,419	40,785,308	65,146,860.85		65,146,860.85
Thermal Electricity	3,066,318	-	298,770	337,182	4,882,361	-	-	690,855,316.36		690,855,316.36
Heat Supply	1,145,160	53,424	1,462,121	844,857	1,274,643	-	-	87,620,322.82		87,620,322.82
							Subtotal	1,816,710,391.46		1,850,545,852.42

nzheng: Allocate all other transformation losses to Industry

Sector - Unit: tons of CO_2 emissions	Fuel Oil	LPG	Refinery Gas	Other Petroleum Products	Natural Gas	Heat	Electricity	Adjusted Subtotal	Other Transformation Losses	Total CO2 Emissions
Agriculture	48,527	117,307	-	-	-	103,034	69,344,994	138,083,832	-	138,083,832.00
Industry	49,249,008	15,605,802	27,163,281	39,041,883	91,016,882	226,355,451	1,817,623,717	4,773,221,157	124,063,357	4,897,284,514.16
Construction	1,219,657	194,939	-	27,193,586	216,213	623,523	28,716,747	83,245,170	-	83,245,170.18
Transport & Telecom	35,600,721	1,730,402	-	-	13,793,944	2,292,102	44,701,938	572,835,642	-	572,835,642.47
Commerce	202,198	1,625,021	-	-	3,876,544	4,300,261	79,538,212	133,423,563	-	133,423,563.11
Residential	-	46,107,246	-	-	37,154,186	79,205,609	343,664,425	721,590,247	-	721,590,247.18
Other (Public Sector)	306,072	1,413,942	-	-	4,568,263	8,394,537	149,546,128	238,871,823	-	238,871,823.10
Thermal Electricity	11,243,167	-	1,095,489	1,236,334	17,901,989	-	-	2,533,136,160	-	2,533,136,159.97
Heat Supply	4,198,920	195,889	5,361,112	3,097,808	4,673,692	-	-	321,274,517	-	321,274,517.01
							Subtotal	6,661,271,435.35		6,785,334,792.21

Tables 6 and 7 are linked to power generation data from the energy balance and included solely as references, and are not used in any calculations.

Table 6: China Electricity Structure - 2008

	Electricity - Mtce	%
Hydro	7,191.95	17.1%
Nuclear	840.56	2.0%
Thermal	34,290.06	81.5%
Import	47.22	
Export	-204.55	
Total	42,070.80	

Table 7: Thermal Power Generation

	Mtce	%
Coal	89,701.86	97.8%
Petroleum	888.62	1.0%
Natural Gas	1,090.20	1.2%

Carbon Sequestration | Calculation Results | Input Non-Fuel Data | Energy balance SCE | 2008 energy balance (physical) | Base Data | Source