Lawrence Berkeley National Laboratory

Energy Use in China: Sectoral Trends and Future Outlook

Authors

Zhou, Nan
McNeil, Michael A.
Fridley, David
et al.

Publication Date

2008-04-18

LBNL-61904

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Energy Use in China: Sectoral Trends and Future Outlook

Nan Zhou, Michael A. McNeil, David Fridley, Jiang Lin, Lynn Price, Stephane de la Rue du Can, Jayant Sathaye, and Mark Levine
Lawrence Berkeley National Laboratory

Environmental Energy Technologies Division

January 2007

This work was supported under U.S. Department of Energy Contract No. DE-AC02-05CH11231.

Please direct correspondence to Jayant Sathaye at JASathaye@lbl.gov and Nan Zhou at NZhou@lbl.gov.

Preface

The past decade has seen the development of many scenarios describing long-term patterns of future Greenhouse Gas (GHG) emissions. Each new approach adds additional insights to our understanding of overall future energy trends. In most of these models, however, a description of sectoral activity variables is missing. End-use sector-level results for buildings, industry, or transportation or analysis of adoption of particular technologies and policies are not provided in global energy modeling efforts.

All major analyses of long-term impacts of greenhouse gas emissions to date rely on scenarios of energy supply and demand. The underlying drivers of all such major scenarios are macro socioeconomic variables (GDP, population,) combined with storylines describing the context of economic and social development. Unfortunately, these scenarios do not provide more detail than the sector level (i.e., buildings, industry, and transportation). This is to say that the scenarios are developed without reference to the saturation, efficiency, or usage of air conditioners, for example. For energy analysts and policymakers, this is a serious omission, calling into question the very meaning of the scenarios. Energy consumption is driven by the diffusion of various types of equipment; the performance, saturation, and utilization of the equipment has a profound effect on energy demand. Policy analysts wishing to assess the impacts of efficiency or other mitigation policies require more detailed description of drivers and end use breakdown.

Based on these considerations and EETD's extensive expertise in energy demand, the goal of this project is to build a new generation global energy and CO_2 emissions model that will be based on the level of diffusion of end use technologies. The model will address end-use energy demand characteristics including sectoral patterns of energy consumption, trends in saturation and usage of energy-using equipment, technological change including efficiency improvements, and links between urbanization and energy demand.

To this end, LBNL has initiated the Global Energy Demand Collaborative to initiate the development of a new generation model. The ultimate goal of the GEDC is a complete modeling system that covers the entire world (by region or country), and covers all economic sectors at the end use level. In the short and medium term, the core GEDC team has performed a series of studies such as: country studies, sector studies, or methodology reports. The first of these reports include:

- Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions
- Energy Use in India: Sector Trends and Future Outlook (forthcoming)
- What do India's transport energy data tell us?
- Residential Electricity in India and What can be done about it

The present report draws upon the expertise developed over many years in the Laboratory's China Energy Group in order to present as complete and detailed picture as possible of the components and trends in energy consumption in the world's largest country.

Disclaimer

Table of Contents

Executive Summary

This report provides a detailed, bottom-up analysis of energy consumption in China. It recalibrates official Chinese government statistics by reallocating primary energy into categories more commonly used in international comparisons. It also provides an analysis of trends in sectoral energy consumption over the past decades. Finally, it assesses the future outlook for the critical period extending to 2020, based on assumptions of likely patterns of economic activity, availability of energy services, and energy intensities. The following are some highlights of the study's findings:

- A reallocation of sector energy consumption from the 2000 official Chinese government statistics finds that:
    - Buildings account for 25% of primary energy, instead of 19%
    - Industry accounts for 61% of energy instead of 69%

- Industrial energy made a large and unexpected leap between 2000-2005, growing by an astonishing 50% in the 3 years between 2002 and 2005.
    - Energy consumption in the iron and steel industry was 40% higher than predicted
    - Energy consumption in the cement industry was 54% higher than predicted

- Overall energy intensity in the industrial sector grew between 2000 and 2003. This is largely due to internal shifts towards the most energy-intensive sub-sectors, an effect which more than counterbalances the impact of efficiency increases.

- Industry accounted for 63% of total primary energy consumption in 2005 - it is expected to continue to dominate energy consumption through 2020, dropping only to 60% by that year.

- Even assuming that growth rates in 2005-2020 will return to the levels of 2000-2003, industrial energy will grow from 42 EJ in 2005 to 72 EJ in 2020.

- The percentage of transport energy used to carry passengers (instead of freight) will double from 37% to 52% between 2000 to 2020,. Much of this increase is due to private car ownership, which will increase by a factor of 15 from 5.1 million in 2000 to 77 million in 2020.

- Residential appliance ownership will show signs of saturation in urban households. The increase in residential energy consumption will be largely driven by urbanization, since rural homes will continue to have low consumption levels. In urban households, the size of appliances will increase, but its effect will be moderated by efficiency improvements, partially driven by government standards.

- Commercial energy increases will be driven both by increases in floor space and by increases in penetration of major end uses such as heating and cooling. These increases will be moderated somewhat, however, by technology changes, such as increased use of heat pumps.

- China's Medium- and Long-Term Development plan drafted by the central government and published in 2004 calls for a quadrupling of GDP in the period from 2000-2020 with only a doubling in energy consumption during the same period. A bottom-up analysis with likely efficiency improvements finds that energy consumption will likely exceed the goal by 26.12 EJ, or 28%. Achievements of these goals will therefore require a more aggressive policy of encouraging energy efficiency.

1. What's at Stake: The Critical Role of Energy Efficiency in China

China's rapid economic expansion has propelled it into becoming one of the largest energy consuming nations in the world, with demand growth continuing at a high pace commensurate with its economic expansion. As the second-largest energy consumer[1], China's energy consumption has a growing impact on world energy markets, affecting the availability of energy resources and global market prices. Foreign governments as well as global oil, gas, coal, and power industry participants are increasingly concerned with understanding and responding to China's emergence as a new and increasingly decisive player in energy markets. At the same time, China's rapidly growing consumption, increasing imports, supply shortages, and difficulties integrating fully into global energy market are placing added pressures on the Chinese leadership to ensure that challenges in energy availability does not constraint its growing economy, which is critical to providing steady rates of employment and rising standards of living for the population. Moreover, because of China's increasing importance in the global energy scene, how Beijing chooses to deal with these energy security questions will not only affect the Chinese economy, but the global economy as well.

China's development over the next 15 years is being guided by a Medium- and Long-Term Development plan drafted by the central government and published in 2004 (NDRC,2005). This document laid out the broad guidelines of China's development from 2000 to 2020, central to which is a quadrupling of GDP with only a doubling of energy consumption. This goal is in essence to repeat the experience of the period from 1980 to 2000 when China did achieve a quadrupling of GDP while keeping energy consumption growth to only half that rate. The 2020 development goal is to be achieved for the most part through a steady increase in industrial, building, and transportation efficiency with the target of reaching international "leading levels" in each sector by 2020. The document is important in its consideration of the limits to China's extensive growth over the past 20 years and recognizing that even a doubling of energy consumption to 2020 is a serious challenge.

By 2005, however, it became apparent that China had substantially exceeded its energy consumption growth target for the first quarter of its 20-year development plan. Instead of maintaining the ratio of energy growth to economic growth at 0.5, China experienced a sharp rise in energy intensity between 2001 and 2005, with the ratio of energy growth to economic growth peaking at 1.45 in 2004. This loss of momentum in continued efficiency gains and intensity reduction called into question China's ability to keep energy consumption growth at just half the rate of economic growth over the entire 20 year period and suggested that energy consumption in 2020—assuming success in quadrupling GDP over the period—would be significantly higher than forecast.

China's 11th Five-Year Plan (FYP) sets an ambitious target for energy-efficiency improvement: energy intensity of the country's gross domestic product (GDP) should be reduced by 20% from 2005 to 2010 (NDRC, 2006). This goal signals a major shift in China's strategic thinking about its long-term economic and energy development. It also provides further evidence that the Chinese government is serious in its call for a new "scientific development perspective" (科学发展观) to assure sustainability in accordance with long-run carrying capacity of the natural environment.

This target for energy efficiency is likely to be difficult to achieve, considering that energy consumption has grown more rapidly than GDP in the last five years. If the recent trend continues, not only will it jeopardize China's development goals, it will also create significantly greater adverse

[1] The chief economist of the International Energy Agency ("IEA") announced that China will surpass the USA as the biggest emitter of greenhouse gases by the end of 2007 rather than in 2010 as previously forecast. See http://www.rossputin.com/blog/index.php/a/2007/05/02/china_to_surpass_us_in_greenhouse_gas_em

environmental impacts and major threats to long-run sustainability. Further, it could introduce a huge "unexpected" disturbance to the global energy and climate system. It is in recognition of the likely costs of "run-away" energy growth that China's leaders have decided to highlight the need to reduce energy intensity.

China's current development plan forms the basis of our baseline scenario evaluation in the study. The baseline scenario incorporates the collective scope of technology choices, efficiency improvements, policy targets, fuel switching, production trends, equipment ownership and other elements of the development plan that China has proposed to shape its energy growth path to 2010. Underlying this scenario is the assumption that the GDP target of 7.5% annual average growth from 2005 to 2010 will be met. Within this scenario, intensity improvement goals are similar to those used in China Energy Development Strategy 2004 by the Development Research Center (RNECSPC, 2005). The long-term development plan, though rich in detail in the industrial sector, omits a range of details in some areas, such as residential appliance ownership. In these cases, we have applied reasoned judgment based on experience working on Chinese appliance efficiency standards and efficiency programs, with additional reference to similar developments in Japan, Korea, and the United States.

The primarily analytical tool used in this study was a accounting framework of China's energy and economic structure, built using the LEAP (Long-Range Energy Alternatives Planning) modeling software. Details of the model structure and underlying data, drivers are presented in Appendix 1. This approach allowed a detailed consideration of technological development—industrial production, equipment efficiency, residential appliance usage, vehicle ownership, lighting and heating usage etc—as a way to evaluate China's energy development path below the level of its macro-relationship to China's economic development path.

2. Methodology and Data

Two general approaches have been used for the integrated assessment of energy demand and supply – the so-called "bottom-up" and "top-down" approaches. The *bottom-up approach* focuses on individual technologies for delivering energy services, such as household appliances and industrial process technologies. The *top-down* method assumes a general balance or macroeconomic perspective, wherein costs are defined in terms of changes in economic output, income, or GDP. Each approach captures details on technologies, consumer behavior, or impacts that the other does not. Consequently, a comprehensive assessment should combine elements of each approach to ensure that all relevant impacts are accounted for and that technology trends and policy options for reducing energy consumption or mitigating climate change are adequately understood.

This section describes the methodologies used to develop an end-use model to provide insights regarding the technologies that would be used, including energy intensity and saturation levels, to reach the energy consumption levels envisioned. A baseline scenario that incorporates targets stated in China's official plans and business-as-usual technology improvement was developed To keep the consistency of the storylines, key driver variables were kept the same.

The model consists of both the energy consumption sector and the energy production sector (transformation sector) including:

- residential buildings,
- commercial buildings,

- industry,
- transportation,
- agriculture, and transformation

Sectoral energy consumption data are available in published statistics. We used China's energy statistics to prepare time series of primary energy use (counting the losses that occur in transformation sector). After building the model from the bottom-up, we calibrated the data by comparing the results of energy use with the statistical data for the base year (top-down).

Key drivers of energy use include activity drivers (total population growth, urbanization, building and vehicle stock, commodity production), economic drivers (total GDP, income), energy intensity trends (energy intensity of energy-using equipment and appliances), and carbon intensity trends. These factors are in turn driven by changes in consumer preferences, energy and technology costs, settlement and infrastructure patterns, technical change, and overall economic conditions.

2.1 Residential Buildings

Residential energy provides numerous services associated with household living, including space heating and cooling, water heating, cooking, refrigeration, lighting, and the powering of a wide variety of other appliances. Energy demand is shaped by a variety of factors, including location (in both geographic location and urban vs. rural) and climate. In developing countries such as China, it is important to divide households into rural and urban locales due to the different energy consumption patterns found in these locations. Within the locales, end uses were broken out into space heating, air conditioning, appliances, cooking and water heating, lighting, and a residual category.

The end uses were further broken out by technologies; some appliances were broken out into classes by level of service, associated with different levels of efficiency. Space heating varies by climate type, so it is broken out by North, Transition and South zones. For all end uses, appropriate devices and fuels were assigned, with saturation (rates of penetration) and energy efficiencies based on statistical and survey data pertaining to the base year (2000) and future values based on analysis of government plans, trends, and comparisons to other countries. Changes in energy demand in the model are in part a function of driver variables, e.g., GDP, population, household size and urbanization rate, which were determined exogenously and included in the model. Table 1shows the breakouts.

Table 1 End-Use Structure of the Residential Sector

End use	Space heating		Air conditioning	Lighting	Cooking and water heating	Appliances		
Category	North	Transition				Clothes Washer	TV	Refrigerator Three sizes
Technologies	Electric heater gas boiler boiler stove district heating heat pump air conditioner		Ordinary efficient Highly efficient	Incandescent Florescent CFL	Electricity Natural gas LPG Coal Coal gas Other	Vertical Horizontal	Black TV Color TV	Ordinary efficient Highly efficient

The equation for energy consumption in residential buildings can be summarized as follows (some subscripts have been omitted for brevity of presentation):

Equation 1. $$E_{RB} = \sum_{i}^{OPTION} \sum_{m}^{OPTION} \frac{P_{m,i}}{F_{m,i}} \times \left[\left(H_{m,i} \times \left(SH_{m,i} \right) \right) + \left(\sum_{j} p_{i,j,m} \times UEC_{i,j,m} \right) + C_{m,i} + W_{m,i} + L_m + R_m \right]$$

where, in addition to the variables above:

m = locale type (urban, rural)
$P_{m,i}$ = population in locale *m* in region *i*
$F_{m,i}$ = number of persons per household (family) in locale *m* in region *i*,
$H_{m,i}$ = average floor area per household in locale type *m* in region *i* in m^2
SH_i = space heating energy intensity in residential buildings in region *i* in kWh/m^2-year,
j = type of appliance or end-use device,
$p_{i,j}$ = penetration of appliance or device *j* in region *i* in percent of households owning appliance (values in excess of 100% would indicate more than one device per household on average),
$UEC_{i,j}$ = energy intensity of appliance *j* in region *i* in MJ or kWh/year,
C_i = cooking energy use per household in region *i* in MJ /household-year,
W_i = water heating energy use per household in region *i* in MJ /household-year,
L_m = average lighting energy use per square meter in locale type *i* in kWh /square meter-year, and
R_m = residual household energy use in locale type *i* in MJ /household-year.

Air conditioner and refrigerator end uses are detailed with stock turnover modeling, which includes information on initial stocks by vintage, energy efficiencies by vintage (allowing explicit modeling of the impacts of standards), efficiency degradation profiles, and lifetime or survival profiles.

2.2 Commercial Buildings

The commercial buildings sector is represented in a fashion similar to residential buildings. A subsectoral breakout includes retail, office, hotel, school, hospital, and other buildings. The key **end uses** by the subsectors listed above include space heating, space conditioning, water heating, lighting, and other uses. The end-uses were further broken out by technologies shown in Table 2.

Table 2 End-Use Structure of the Commercial Sector

End use	Space heating	Space cooling	Lighting and other appliances	water heating
Technologies	Electric heater gas boiler boiler small cogen stove district heating heat pump	Central AC Room AC Geothermal Heat Pump Central AC by NG	Existing Efficient	electric water heater gas boiler boiler small cogen oil boiler

Omitting repetitive subscripts for the energy intensity terms, this can be represented as:

Equation 2. $$E_{CB} = \sum_{k}^{OPTION} \sum_{n}^{OPTION} \sum_{q}^{OPTION} \left[A_{CB,n} \times P_{q,n} \times \left(\sum_{k} Intensity_{q,n} \times Share_{k,q} / Efficiency_{k,q} \right) \right]$$

where, in addition to the variables listed above:

k = fuel type (technology type)
q = type of end use
$A_{CB,n}$ = total commercial floor area in commercial building type n in m^2
$P_{q,n}$ = penetration rate of end use q in building type n
$Intensity_{q,n}$ = intensity of end use q in building type n
$Share_{k,q}$ = type of technology k for end use type q

$Efficiency_{k,q}$ = efficiency of technology k for end use type q

2.3 Industry

The industry sector is divided into seven specific energy-intensive industries (iron and steel, aluminum, cement, glass, paper, ethylene, ammonia) and the residuals. Physical energy intensities in terms of energy use per ton (or other unit) of industrial product produced for each industrial sector are used. Physical production values are multiplied by industry average physical intensities and then summed to derive energy consumption values for the energy-intensive industries. Any other industrial production is treated as a remainder. Energy use in the residual category is simply the product of industry value added GDP, and the residual energy use in industry per unit of GDP (economic energy intensity), given the total industry energy consumption from the statistical yearbooks.

The end-uses were further broken out by technologies shown in Table 3.

Table 3 Subdivision of the Industry Sector

End use	**Iron and Steel**	**Aluminum**	**Cement**	**Glass**	**Paper**	**Ethylene**	**Ammonia**		
Category or feed stocks				Flat		Naphtha Feed Stock	Coal and coke	NG	Fuel Oil
Fuel	Coal Coke Electricity NG Heavy oil	Coal Coke Electricity Diesel Heavy oil	Coal NG Electricity Heat	Coal Heavy oil NG Electricity Heat	Coal Heavy oil NG biomass Electricity heat	Naphtha Electricity Heat	Coal Electrici ty Heat	NG Electri city Heat	Heavy oil Electri city Heat

Equation 3. $E_{IN} = \sum_{k}^{OPTION}\left[\sum_{c}^{OPTION} Q_c \times EI_{c,k}\right] + G_v RI_k$

where, in addition to the variables listed above:

c	=	commodity type
Q_c	=	quantity of energy-intensive commodity *c* produced,
$EI_{c,k}$	=	average intensity of fuel type *k* for producing energy-intensive industrial commodity *c* in GJ/metric ton (or other physical unit),
G_v	=	Industrial value added GDP, and
$RI_{,k}$	=	average intensity of energy type *k* for producing residual, i.e. remaining industrial GDP.[2]

2.4 Transportation

In a fashion peculiar to the transport sector, final energy is employed in a large variety of modes and technologies to provide a small range of end-use services, i.e., the transport of passengers and goods, ultimately representing a single service: *mobility*.

While for the other sectors the combination of fuel and technology is nearly always sufficient to determine the end-use service provided, this is not necessarily true for transport. Neither does the combination of the end-use and technology alone provide a level of detail adequate to accurately estimate end-use energy demand. For example trucks and locomotives used to haul freight can share the same engine technology and fuel and provide the same end-use service, but the associated energy intensity will be significantly different.

Transport could be broken out by *mode*:
- water (internal waterways vessels, sea transport vessels, international transport vessels)
- air (national and international air transport),
- rail (intracity and intercity mass transit)
- pipeline (subdivided by good delivered, when detail is available)

For China, urban and rural transport on Road could exhibit very different energy intensities. Thus, it was broken out by urban and rural; the urban module is divided into cars, taxis, motorcycles and buses, while the rural module is divided into cars and motorcycles. The highway module is comprised of primarily of buses which are subdivided into Heavy Duty, Medium Duty, Light Duty and Mini Buses (see Table 4).

Table 4 Subdivision and End-Use of the Transportation Sector

					Fuel
passenger	road	urban	cars		Gasoline, Diesel, NG, Hybrid
			Taxis		Gasoline, Diesel, NG
			Buses	Heavy duty, medium duty, light duty, minibus	Gasoline, Diesel, NG
			Motorcycles		Gasoline, Diesel, NG
		rural	cars		Gasoline, Diesel, NG
			motorcycles		Gasoline, Diesel, NG
		highway	Buses	Heavy duty, medium duty,	Gasoline, Diesel, NG

[2] This residual can be derived based on historic and projected trends in the share of energy use or industrial sector GDP of light industries compared to energy-intensive industry in a country or region.

				light duty, minibus	
	rail	Intercity			Diesel, electricity, Fuel oil, Steam
		local			Diesel, electricity, Fuel oil, Steam
	water	Inland			Diesel, Fuel Oil
		coastal			Diesel, Fuel Oil
	air	Domestic			Jet Kero, Avgas
		International			Jet Kero, Avgas
Freight	road	urban	Trucks		Diesel, Gasoline
		rural	Trucks		Diesel, Gasoline
			Tractor	Heavy duty, medium duty, light duty, minibus	Diesel
			Rural Vehicle	Three wheeler, four wheeler	Diesel
		highway	Trucks	Heavy duty, medium duty, light duty, minibus	Gasoline, Diesel
	rail	Intercity	Coal, oil, coke, other		Steam,diseal, electricity
		local			Steam,diseal, electricity
	water	Inland	Coal,oil and oil product, crude oil, other		diesel
		coastal	Coal,oil and oil product, crude oil, other		diesel
		Ocean			Fuel oil
	air	Domestic			Jet Kerosene, Avgas
		International			
	Pipeline		Crude oil, oil products, NG, other Gas		electricity

The **physical energy intensities** used are in terms of energy use per km, per passenger-km, or per tonne-km.

This can be summarized as follows:

Equation 4. $$E_{TR} = \sum_{k}^{OPTION} \sum_{t}^{OPTION} \sum_{r}^{OPTION} \sum_{j}^{OPTION} Q_{t,r,m,i} \times s_{t,r,j,i} \times f_{k,t,r,j,i} \times EI_{TR,k,t,r,j,i}$$

where, in addition to the variables above described:

j = transport technology class (e.g., vehicle classes),
$s_{t,m,i}$ = share of transport services *t*, delivered through the mode *m* employing the transport end-use technology *j*, and
$f_{k,t,m,j}$ = share of fuel *k* used for technology *j* in providing transport services of type *t*.
r = mode type (road, rail, water, air, pipeline)
m = locale type (rural, urban)

$Q_{t,r,m}$ = quantity of transport service of type *t* in mode *r* and in locale *m* of region *i* in passenger-km and tonne-km, and

$EI_{TR,k,t,,m}$ = average energy intensity of energy type *k* for transport service of type *t* in mode *r* and in locale *m* in MJ/(passenger-km-year) and MJ/(tonne-km-year).

k = fuel type

t = transport type (passenger, freight)

Turnover data series for rail, water, air and intercity highway road can be acquired from China Statistical Yearbooks and the Transportation Yearbooks for different years. However, such data does not exist for vehicles intra-city or intra-rural. Data on stocks and the usage pattern (such as average travel distance and the annual amount of the trips) were used to calculate the total turnover.

2.5 Agriculture

Energy use in agriculture was modeled simply as the product of agriculture value added GDP, and the energy use in agriculture per unit of GDP (**economic energy intensity**), given the total agriculture energy consumption from the statistic yearbooks. Historic agriculture energy consumption is available in the China Energy Databook.

Throughout this report energy consumption values are displayed in two different forms: primary and final energy consumption. Final energy consumption represents energy consumed directly by the end user while primary energy consumption includes final consumption plus the energy that was necessary to produce secondary energy, such as energy transformation loses in electricity production (Price, 2006). The efficiency of non fossil fuels such as nuclear, wind and hydro were treated the same as coal power plant, so that primary resource requirements for fossil fuels and hydro can be easily compared

3. Energy Use in China

China contributed 31% of the world's energy consumption increase from 2003 to 2004. The growth of the Chinese energy demand was 16% between 2003 and 2004. Around 37% of the world's electricity consumption increase in 2004 is due to China (IEA, 2005.2006. NBS, 2005). China has been the main driver of world energy demand growth, and the phenomenon is accelerating.

3.1 Historical Energy Use By Energy Type

China's goal of quadrupling GDP by 2020 with only a doubling of energy consumption is based largely on the experience of the 20-year period between 1980 and 2000 when this same target was successfully achieved. As shown in Figure 1, China's energy consumption grew from a total of about 25 EJ in 1980 to 48 EJ in 2000 (including biomass use). At the same time, GDP per capita jumped from US$172 to US$853. Consistently across the entire period, however, was the dominance of coal in the energy structure. From 51% of total energy consumption in 1980, the share of coal actually crept higher by 2000, when it accounted for 54% of total consumption[3]. Even as oil, natural gas, hydro and nuclear power use have grown substantially in volume during this time, China's economic growth relied primarily on a steady supply of domestically produced coal, for which its reserves are estimated as the third largest in the world (WEC 2001).

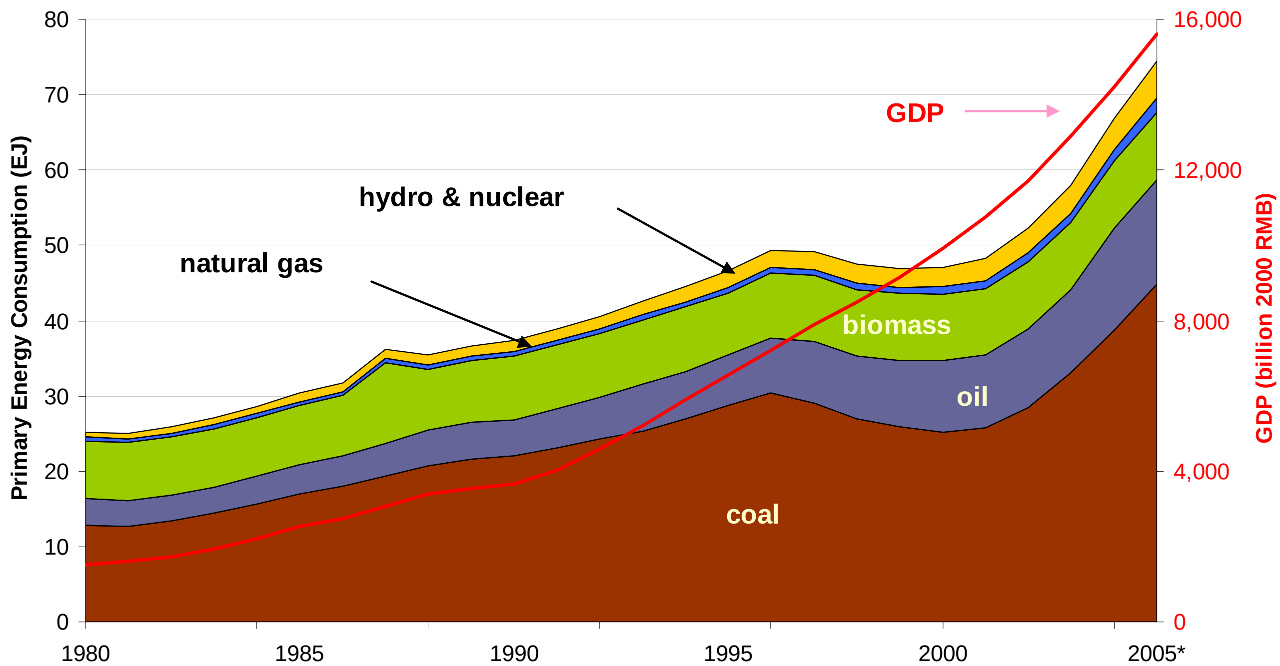
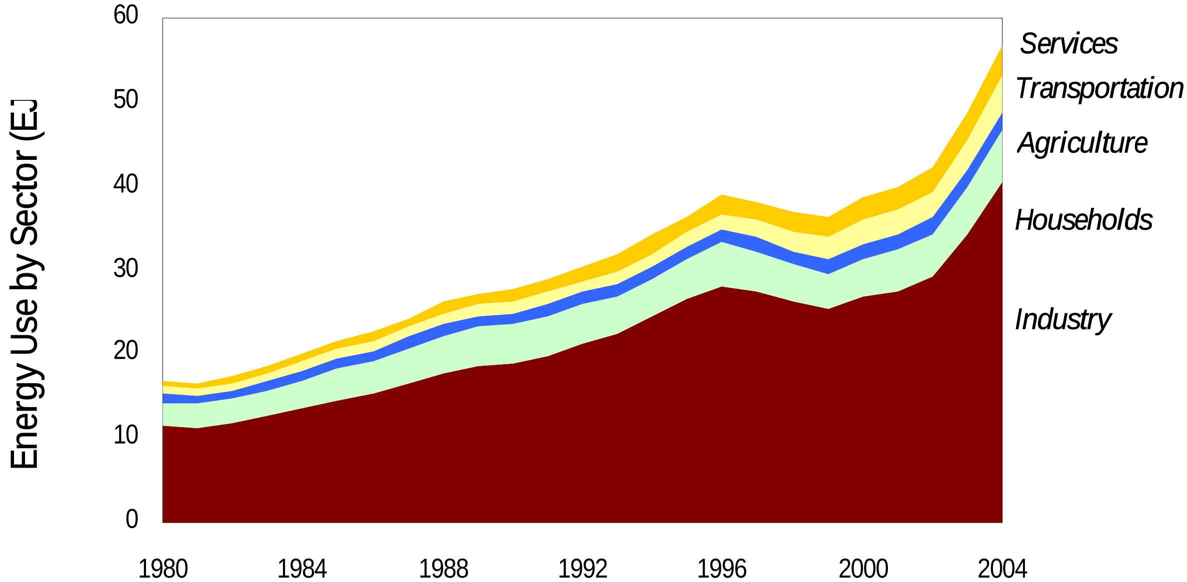


Figure 1 Historical Trend of Energy Use by Fuel

[3] The reported fall in China's coal use and energy intensity after 1995 was very significant, but the underlying data have been challenged. Much of the uncertainty focuses on coal production data; coal consumption data are of much higher quality. Driving factors behind the decline include: closure of inefficient plants, behavior changes and reforms; slowing economic growth; fuel switching, improved energy efficiency and subsequent rise, etc...(Sinton and Fridley,2003)

3.2 Historical Primary Energy Consumption by sector



Note: in primary term excluding biomass, Source: CSY

Figure 2 Historical Energy Use by Sector in Statistics

The trend in end-use sector energy consumption can vary widely, according to the level and pace of economic development in a given region. On a worldwide basis, energy demand in the industrial sector grows the slowest, at an average rate of 1.5 percent per year from 1971 to 2000 (Price, et al., 2006). In contrast, taking account of the losses occurred in transformation sector, service sector energy consumption has grown the fastest at an AGR of 7% from 1980 to 2004 in China, slower growth can been observed in household sector at 5.4% (Figure 2). Growth in the industry sector is 5.1%. The slowest growth in energy demand among the end-use sectors is transportation and agriculture sector at 3.5% and 3.4% respectively per year. The fast growth in building sector can be attributable to the soaring demand for electricity, thus the growth rate would be different if losses in electricity supply were not allocated among the sectors, which is generally presented as final energy use.

As will be discussed further in following sections, China's official energy statistics provide information on the supply side but do not detail demand by end use, therefore sectoral energy use and its breakdown has long been questioned. In building energy consumption, for example in 2004, the revised statistic shows 70.9% of the energy used in the industry sector, 11% in residential sector, and 6.5% for the "Service plus Other" sector, while the commercial sector alone consumes 13% of total final energy use in IEA countries (IEA,2004). Therefore the use of the sectoral energy consumption data in the statistics should be limited to extracting the historic growth trend.

3.3 Historical Primary Energy Per GDP and Per capita

3.3.1 Population growth and Urbanization

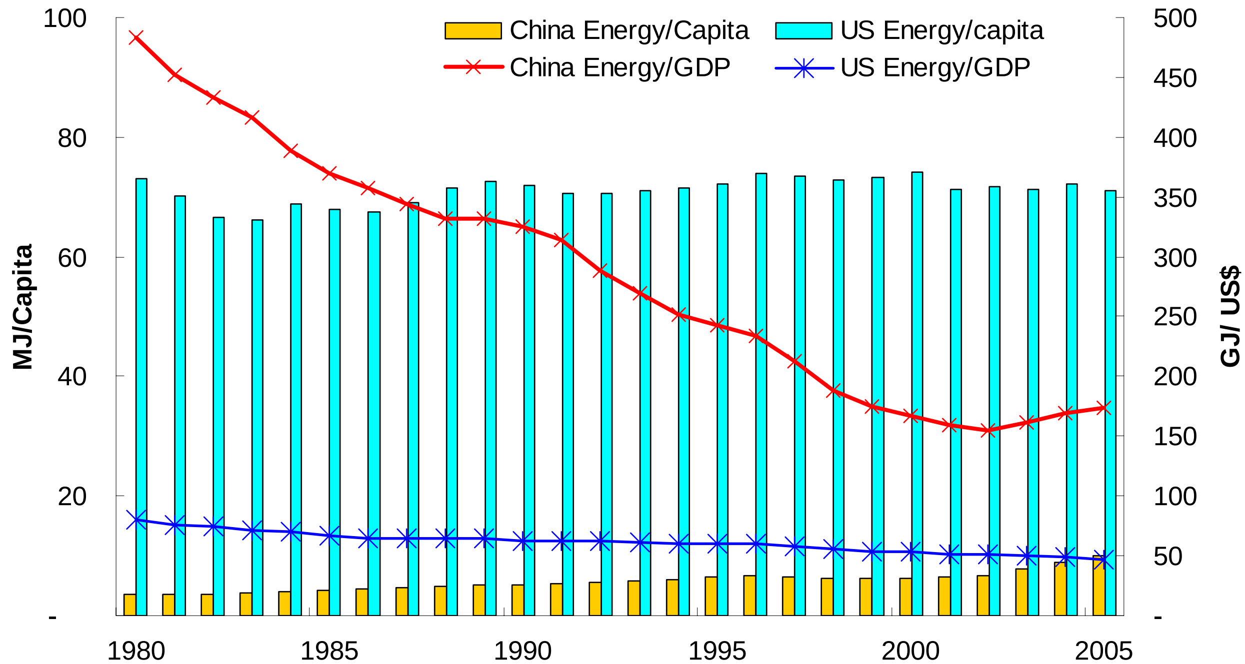
World population is currently growing at a rate of 1.2 per cent annually, implying a net addition of 77 million people per year. China accounts for 12% of that annual increment (UN,2004). Urbanization rate is a key energy driver since urban households generally have higher demand for energy services than do rural households. This is supported by the fact that people living in urban areas are wealthier and have a higher standard of living than the rural population. The UN projection (UN 2005) projects the most recent urban-rural growth difference observed by assuming that the proportion of urban population follows a logistic path that attains a maximum growth rate when the proportion urban reaches 50% and whose asymptotic value is 100% (UN 2003). The resulting UN urbanization rate projected for China in 2030 is 61% (UN 2003).

3.3.2 Stage of economic development

Economic growth in turn was supported by a wide range of government policies that encouraged, mandated or supported the adoption of more efficient equipment and production processes. Some policies were directly interventionist, such as the establishment of energy consumption quotas, while others, such as two-tiered pricing of some energy products, encouraged efficiency as a way to reduce energy consumption and production costs (Wang, 1995). Taken in whole, the range of efficiency and conservation measures in place during the 1980s and 1990s helped to keep China's energy demand growth consistently below the rate of economic growth, reducing energy intensity by about 65% by 2000. After 2001, however, this long-term trend came to an end as an acceleration of economic growth coincided with rapidly rising energy consumption, which in 2002, 2003, and 2004 substantially exceeded the rate of economic growth, and averaged 13% per year (Figure 1). The loosening of credit controls has been cited as a key change stimulating rapid growth in capital investment, including rising levels of government-directed investment in the national infrastructure, including highways, rail, airports, subways, bridges, ports, and other major construction projects. Heavy industrial capacity and production in basic sectors such as cement and iron and steel jumped, strongly pushing up industrial energy consumption. Despite these challenges, economic growth remained consistently high, averaging 9.1% per year between 2000 and 2005. By 2005, then, China had exceeded both its GDP target (7% per year average) and energy target (3.5% per year average).

3.3.3 Historical Primary Energy per GDP and per capita

While the per capita energy consumption in China is still low compared with other countries, it has been growing continuously, except for the period of 1997 to 2001. It is also consistent with the trend seen in other developed countries. With a growing economy and increasing living standards, per capita energy use and carbon emissions are expected to continue to rise (Figure 3).



Source: CSY, 1985-2006. EIA, 2006a

Figure 3 Energy Consumption per GDP and per Capita[4]

3.4 Calibration of the Energy Consumption Data for 2000

Reliable and accurate data are critical to good analysis for policy and business. China's official energy statistics provide information on supply side. The energy data reports production of all energy sources in all regions, and consumption by fuels and sectors. However, it only has limited information on energy demand by end use. Further, China uses a different classification system for energy reporting, so the sectoral energy breakdown has long been questioned. It is particularly an issue for building energy consumption, for example in China's statistics it only accounts for about 19% of total, while it is about 38% in total non OECD countries (IEA, 2006). Many analysts and even government agencies use this figure to evaluate China's current energy status and make projections of China's Energy future which could be misleading or wrong.

In addition, lack of the information on end use demand could also lead to inadequate ability to capture the potential for efficiency improvement and the impacts of efficiency policies and programs. Therefore it is crucial to evaluate and understand the reality rather than simply using it as many of the energy analysts have done.

The authors have applied reasoned judgments based on long term experience in working on Chinese efficiency standards and energy related programs to present a realistic interpretation of the current energy data. Our bottom-up approach allows a detailed consideration of end use intensity, equipment efficiency, etc—as a way to apply judgments, and thus easy assessment of impacts of specific policy and technology on building energy use.

---

[4] GDP converted with exchange rate, 2000 constant US$

In this chapter, a comparison of Chinese official energy data and data estimated by LBNL will be discussed in both setoral breakdown and fuel mix, with a focus on the building sector.

3.4.1 Sectoral Breakdown

Jonathan Sinton (2001) has addressed the 'Accuracy and Reliability of China's Energy Statistics'. He demonstrated that since early 1980s, National Bureau of Statistics (NBS; formerly the State Statistical Bureau) began publishing detailed energy consumption statistics by sector, and provincial and national energy balances. These sets of energy statistics have been long been considered the best, most comprehensive source of national-level energy data for China, and they are the starting point for statistics published by many organizations (e.g., IEA, 2000; Sinton, et al., 2004; EIA, 2001; BP-Amoco, 2001). Sinton also points out that changed in definitions and coverage has raised questions about reliability of trends observed over time; Problems like misreporting or non-reporting, and the difficulties in adapting the systems of data collection to rapidly changing social and economic structures have led to doubts about the accuracy of some indicators, especially economic output; Some sectoral and categorical definitions do not accord with accepted practices in many other countries, and contradictions between some statistics have appeared.

In December 2005, NBS revised its 2004 nominal GDP upwards by 16.8% or Rmb 2,336.3 billion (US$281.9 billion), and also revised the energy consumption from 2000 to 2004 soon after in 2006. Energy consumption rose 2.7% for 2000, with most of the increase in industry sectors (NBS, 2005). In 2000, the revised statistic shows 69% of the energy used in industry sector, 12% in residential sector, and 7% each for commercial sector (Service plus Other) and transportation sector. For comparison, the commercial sector consumes 13% of total final energy use in IEA countries (IEA, 2004). The discrepancy may be attributable to Chinas uniqueness of the traditional classification. For example a work unit or danwei is the place of employment, and also the living quarters. Many residential and commercial energy uses associated with industrial enterprises or plants have been reported as industry energy use. Similarly, many transportation oil uses were treated as energy use within industrial, agriculture, and building sectors. Although it remains unclear how much energy should be reallocated back to the sectors that fits the classification used internationally, our bottom-up modeling and analysis enables us to evaluate all major driving forces behind patterns of energy use, provide with end-use energy consumption information needed to understand patterns of energy demand.

Figure 4 left illustrates primary energy consumption by sector in Chinese statistics; right shows the adjusted results from our analysis. With the reallocation of transportation oil use back and building energy use back from industry sector, the energy consumption in industry sector has been reduced to 61% of the total; simultaneously commercial sector has increased to 9%, residential sector to 16%, transportation sector to 10% in 2000. The detailed break down input will be discussed later.

Similar insights could be found in some analysis done by Chinese governmental institute as well. In Chinese State Department and National Development and Reform Commission jointly conducted *Research on National Energy Comprehensive Strategy and Policy of China (RNECSPC,2005)*, it shows the building energy consumption accounts for 26.9% of the total in 2000 and 26.5% in 2001[5]. Table 5 shows the building energy consumption from 1996 to 2001 extracted from the *RNECSPC*. In the discussion section, the report also that explained the data were obtained from the Ministry of Construction[6], which has big gap with National Bureau of Statistics (NBS)'s statistics, and it could

[5] In page 447, Table 5-51

[6] the Ministry of Construction does survey and collects their own data, but the collecting methods and definitions may

be attributable to the reporting mechanism, in which many building energy consumption were counted as a part of industrial energy use. In addition, it also mentioned that the building energy consumption generally accounts for 30% of the total primary energy in average in the world, and residential sector uses twice as much energy as commercial sector.

Furthermore, Wang qingyi (2005) indicated the building and agriculture together account for 27.6% of the total final energy, which is already higher than the figure in primary terms in the official statistics.

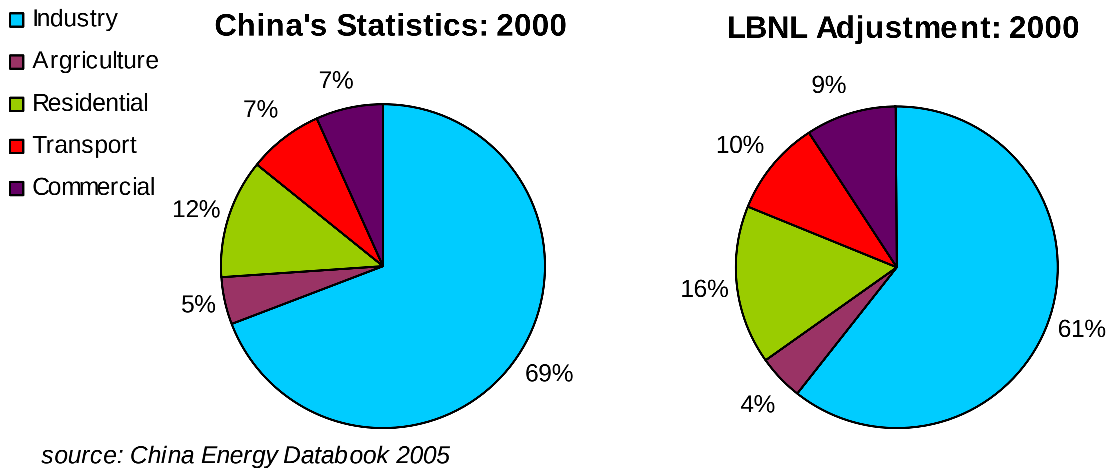


Figure 4 The Primary Energy Consumption by Sector : LBNL estimates shows more energy used in building sector

Table 5 Building Energy Consumption in *RNECSPC*

Year	Energy consumption of nationwide total, Mtce	Building energy consumption, Mtce	Percentage of total, %
1996	1389.5	334.7	24.1
1997	1381.7	341.4	24.7
1998	1322.1	345.7	26.1
1999	1301.2	349.0	26.8
2000	1303.0	350.4	26.9
2001	1349.1	358.0	26.5

3.4.2 Adjustment in fuel mix

As discussed above, End-use fuel consumption in China is recorded by the sector in which the consumption occurred, not by the purpose for which it was used. As another result of the bottom-up analysis, fuel mix among the sectors has also been adjusted. Gasoline consumption, for example, is divided among the major users (agriculture, industry, commerce, transport, residential), even though gasoline provided transportation services in these sectors. Internationally, such consumption would typically fall just in the transportation sector. In this section, we have adjusted transport fuels (gasoline, kerosene and diesel) consumption figures from the original Chinese treatment to agree more closely with international statistical norms.

not coincide with those of NBS's.

Gasoline. It is assumed that all but a small volume of gasoline is used for transportation purposes. All volumes from other sectors have thus been allocated to the transportation sector and subtracted from the other sectors.

Diesel. Based on a study done in the 1990s (Sinton,1996), we have reallocated 20% of agricultural diesel use, 10% of industrial, 12% of commercial, and 10% of residential diesel use to the transport sector and subtracted from the other sectors.

Jet Kerosene. Jet kerosene is not broken out from lamp kerosene in the Chinese energy statistics. From apparent consumption figures (production plus net imports), it is apparent that jet kerosene constitutes the largest proportion of total kerosene use. In this balance, the volume allocated to the transport sector (i.e. national and regional airlines) is used as the jet kerosene total. However, the "other" (government, schools, hospitals) sector consumes about 30,000 b/d of kerosene (Source); it is unclear if this is jet fuel (perhaps military jet fuel) or lamp kerosene, and this volume has been excluded from the transportation adjustment.

Fuel oil. Fuel oil consumption figures include fuel oil used as bunker fuel. It is assumed that the volume allocated to the transportation sector captures most if not all of the bunker fuel usage.

Other Fuels. A small volume of LPG and crude oil are recorded for transportation use. LPG is used in transport is primarily in urban taxis, and crude oil is used in a minor way in the fuel mix for pipeline transportation.

If this adjustment is not made, transportation oil use is understated. In 2003, for ex-ample, "official" transportation oil use constituted only 26% of total oil consumption. On an adjusted basis, this proportion rises to 38%. All discussion of transportation oil use in this report refers to the adjusted figures, and the LEAP model is calibrated based on this adjustment.

4. Sectoral Energy Use in China

Many researches including IEA use the term *final* energy consumption to measure the energy use. However final energy consumption is the energy ultimately consumed by the end-user and does not account for the losses occurring in the transformation of electricity or of other secondary energy product. It is essential to keep in mind that electricity requires up to three times more energy for its production than is consumed directly by the end user. We use the term *primary* energy to take account of the energy used in transformation and final energy term for delivered energy.

4.1 Residential Sector

4.1.1 Energy consumption by fuel and end-use

The adjusted residential energy consumption was 6.6 EJ in 2000, accounting for 16% of primary energy without counting biomass fuels which are mostly used for rural space heating and cooking. It would be 30.6% if biomass is counted. The energy is mostly used in urban area because the rising income have allowed acquisition of home appliances, in addition to the existing central heating system in northern China, which resulted in much larger share of electricity, coal and gas use.

Despite the larger share of land area and more population (64.4%) in rural China, the primary energy use is only 1.84EJ, accounting for 28% of the total residential energy use.

Besides biomass, coal is the dominant fuel within residential primary energy, accounting for 79% of energy consumption in households not including biomass (Figure 5 and Figure 6). This includes the coal direct use for heating and coal used to generate electricity used for appliances. Oil use (principally kerosene) is mostly seen in rural lighting. Even though renewable energy has increased drastically, its share remains insignificant (share).

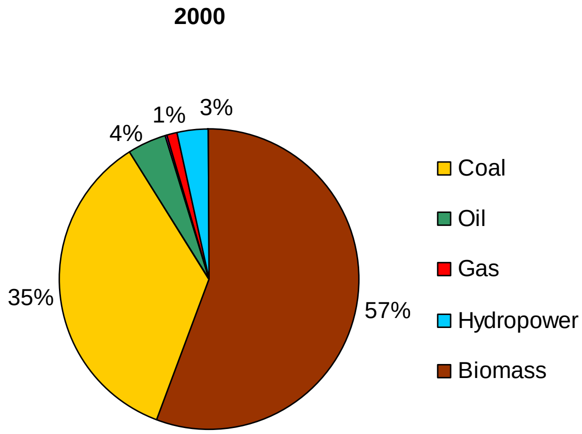


Figure 5 Residential Final Energy Consumption by Fuel (with Biomass)

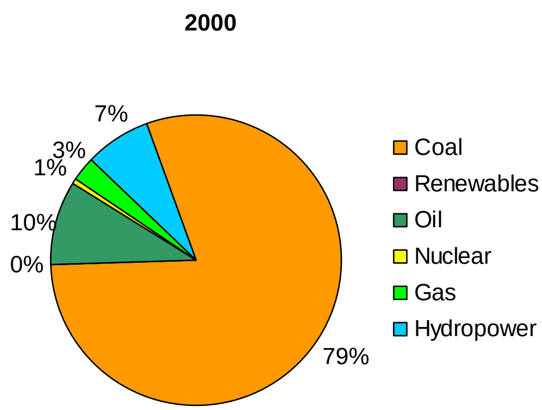


Figure 6 Residential Primay Energy Consumption by Fuel (without Biomass)

Most of the energy was used for space heating and water heating, accounting for 59% of the residential energy consumption (Figure 7). The four major appliances including air conditioner, refrigerator, clothes washer and TV use about 21% of household energy, followed by lighting at 9% and cooking at 7%. Other use which accounts for residual appliances such as computers, printers, etc.., uses only 4% of energy in 2000. For comparison, according to IEA (2004) in 1998, the share of appliances in residential energy use had increased to between 10 and 15% in most European countries, with more than 20 % in the U.S. and Australia and 29% in Japan. Although its share has declined, space heating still account for more than half total residential energy consumption in most of the IEA-11 countries[7]. While energy demand for space heating naturally varies with the climate, it is also determined by the household income level and other factors. Many households in China do not have sufficient heating due to poverty, and traditionally, there were no heating supply system in

[7] The countries include: Australia, Denmark, Finland, France, Germany, Japan, Italy, Norway, Sweden, UK, and the U.S.

Southern China, where the temperature can get very low in the winter. Also, a housing stock with high proportion of apartments (in contrary to single house) would need less space heat per unit area than one with a low proportion (Schipper, 1992). These all possibly contributed to the lower share of space heating demand in China in 2000.

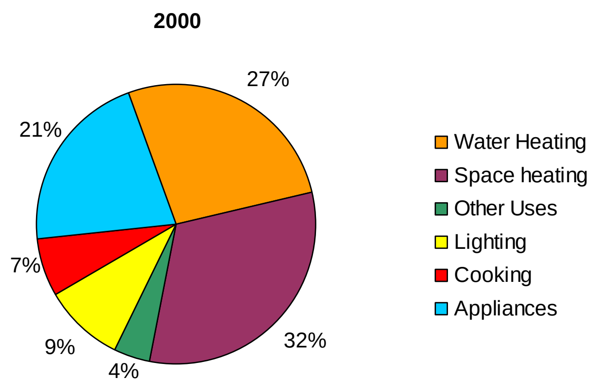


Figure 7 Residential Energy consumption by End-use

4.1.2 Key drivers: Urbanization, Household size, Living area Urban and Rural area

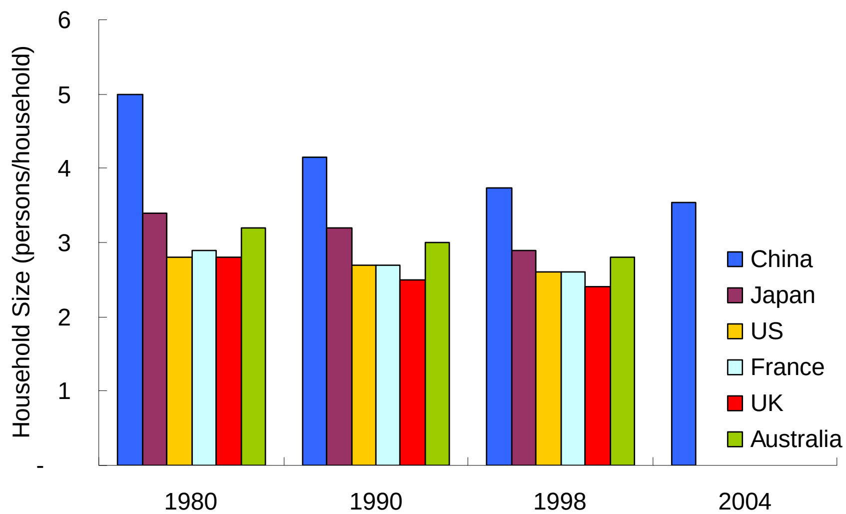
Along with population size, key activity drivers of energy and demand in residential buildings are rate of urbanization, number of households, per capita living area, persons per residence. As populations become more urbanized and areas become electrified, the demand for energy services such as refrigeration, lighting, heating, and cooling increases. In the residential buildings sector, the level of energy demand is further influenced by household income, number of households, size of households, and the number of people per household. Although GDP is not a direct driver in our analysis, it is however used as reference to drive the increase of average household living area and saturation of appliances. Income and wealth effects have been strong generators of demand for durable and nondurable goods and services. In turn, the demand for inputs, including energy, to produce these goods and services would also rise strongly (Battles and Burns, 2000)

The key drivers used in our disaggregating effort are presented in Table 6. The population in 2000 is 1.27 billion and 34.3% of them live in north China, 30% in the South, with the rest live in transitional area. The regional split is used to estimate the energy demand in each region according to climate differences differs and determine the level of the space heating and space cooling needs. Urbanization rate is an important driver for developing countries, where the energy usage characteristics in rural areas could be very different than that of urban. The number of people living in urban areas in China is 35.6% of the total, which is almost the level of the world average in 1970 (U.N. 2006). In general, higher levels of urbanization are associated with higher incomes and increased household energy use (Sathaye et al., 1989; Nadel et al., 1997). Historically, the average household size has been declining in most of the developing countries (Figure 8). China adopted one child policy in 1979 which accelerated this decrease. Average household size declined from 5 persons in 1980 to 3.7 persons in 2004, and in urban China it has almost reached the level of developed countries. Change in household size is important because per capita energy use rises as household size decreases, since a small household have many of the same appliances as a large household and use same amount of energy for heating and cooling (Schipper and Meyers, 1992) . Another important factor is the dwelling area. Existing research shows that dwelling area often increases even during recessions in many countries and the variations offer an important explanation of differences in per capita space heating needs among countries (IEA, 2004). Dwelling area in China has increased significantly over the past two decades with an AGR of 4.3% while it is only about 0.6% in other countries (Figure 9) In 2000, the average dwelling area in China was 94 m^2 per dwelling on average, which has already reached many of the developed countries level in 1998. For instance, France is 88 m^2, Japan is 93 m^2, UK is 85 m^2 and Canada is 127 m^2 respectively in 1998 (IEA, 2004).

Table 6 Macro Drivers in Residential Sector

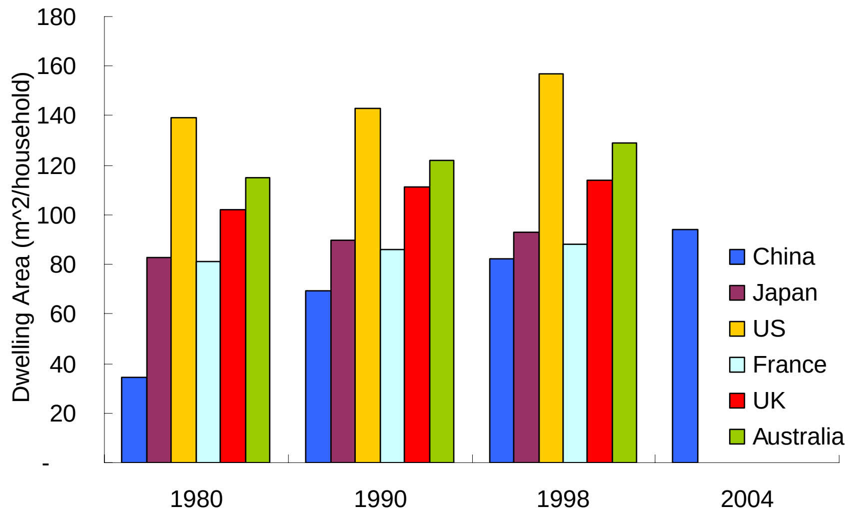
			2000
Population		billion	1.269
	north	percentage	34.3%
	transition	percentage	36.2%
	south	percentage	29.5%
GDP		billion 2000 constant US$	1,198
GDP per capita		US$ /person	944
Urbanization rate		%	35.6
Household size			
	urban	Person	3.19
	rural	Person	4.35
Living area			
	urban	m^2/capita	19.8
	rural	m^2/capita	24.8

Source: NBS, 2004



Source: IEA,2004; NBS,2004

Figure 8 Trends in Household size



Source: IEA,2004; NBS,2004

Figure 9 Trends in Dwelling Area

4.1.3 Energy Use and Activity

Overall energy intensity in the buildings sector can be measured using energy consumption per capita values. We summarize the saturation and aggregated energy intensity on each of the main residential energy end uses in Table 7. Energy intensity trends in residential space conditioning are affected by climate, building thermal integrity, and the heating and cooling equipment used.

Space heating is an important end-use in the developed countries and in some developing countries. Buildings that are centrally heated consume almost twice as much energy as those heated by small room heaters. Heating equipment has been used throughout northern China, but only 30% of the urban area and 8% of the rural area in transition area has heating devices. In northern urban areas, stoves and boilers are the major heating equipment with a share of 40% respectively, followed by district heating of 22%, while in rural, biomass is the major heat source, with a share of 85%. In central China, electric heaters are the major heating with the share of 60% (Zhou, 2002). Buildings in North and Transition urban area are supposed to meet the 2001 building codes[8]. Space heating intensity is 31.60 W/m^2-degree day in north and 17.5 W/m^2-degree day in transition region in 2000. Rural China has much lower heating intensity because of the income gap with urban, which is 2.34 W/m^2-degree day in north and 0.14 W/m^2-degree day in transition region in 2000.

Cooking and water heating intensity in urban areas is 1252 kWh/household per year and slightly more in rural areas. This is much lower than that of Japan in 2000 which was 4560 kWh/household (IEEJ, 2003). In developed countries, the energy consumption of water heating is approximately 5 times as much as that of cooking. Although no data exist to break the two end uses down, the trend in developed countries can serve as a reference. Water heating energy is 4.7 higher than cooking energy in the U.S. and UK, 3.5 times higher in Japan in 1998 (IEA, 2004), and 4.22 times higherfor Japan in 2000 (IEEJ, 2003). We assume that a similar ratio also applies for China. LPG is a major energy source, while coal and electricity are also used in some parts of China. Biomass is the major energy in rural area.

[8] Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone,2003

For lighting, an aggregated lighting intensity was used based on our previous research (Lin, 2003). The annual lighting energy intensity for 7 major cities in China is 213 kWh/household in 1999. The share for different bulbs is 55% for incandescent, 39% for fluorescent and 6% for CFL (compact fluorescent).

Energy use in appliances is determined by ownership or saturation rate and the unit energy consumption (UEC). Ownership rates often grow as a result of economic development. In 2000, refrigerators, TV and clothes washers have already penetrated much of the households in urban areas, while the rates in rural area are still much lower. The use of air conditioning is highly dependent on the climate as well as the income level, therefore on average the ownership is only about 30% in urban China, and very rare in rural. These numbers are much lower than those of developed countries such as 121% for refrigerator and 217.4% for air conditioner in Japan in 2000 (IEEJ, 2003). Unit energy consumption for a given type of appliance depends on not only the efficiency, but also on the usage pattern. In addition, change in the size and features of appliances plays a major role in determining the UECs. Increases in average size are most significant for refrigerators. Although our analysis on refrigerators was broken out into three sizes and three efficiency classes and stock turnover analysis is used, only aggregated and average numbers are presented here for comparison with other countries. Table 7 also shows that most of UECs of the appliances are higher those of Japan, indicating a large potential for energy efficiency improvement.

Table 7 End Use Saturations and Intensities

	Saturation, %		End use intensity/UEC				
	Urban	**Rural**	**Unit**	**Urban**	**Rural**	**Japan**	**notes**
Space Heating							
North	100	100	kWh/m^2-year	79	5.9	38.6	2000 average
Transition	30	8	kWh/m^2-year	26.6	0.24		
Refrigerator	80	12	kWh/year	460	460	380	2004 for 250L-300L
Clothes washer	91	29					
vertical	63	70	kWh/year	36	36	21.9 to 40.2	2004 for 4.2 kg
horizontal	27	30	kWh/year	61	61		
TV							
black	0	53	kWh/year	38	38		
color	117	49	kWh/year	150	150	79	2004 for 29 inch
Air Conditioner	31	1	kWh/year	388	375	229	2000 average
Cooking and water heating	-	-	MJ/household-year	4506	4986	16420	2000 average
Other use	-	-	kWh/year	280	100	16546	2000 average
lighting	-	-	kWh/household	283	253		

4.2 Commercial Sector

4.2.1 Energy consumption by fuel and end-use

Adjusted residential energy consumption was 3.75 EJ in 2000, accounting for 9% of primary energy excluding biomass fuels. Figure 10 shows the primary energy use by fuel in the commercial sector. Coal is the dominant fuel, accounting for 89% of primary energy consumption in total, and 58% if in final energy consumption term which includes only the direct use of coal mostly for space heating and water heating (Figure 11). On top of it, there is also 20% heat that is produced either from small CHP or district heating. Electricity use accounts for 15% of the final energy. This figure is different than that of the IEA countries, where coal use at the end use level only accounts for small tiny portion in total, and electricity accounts for nearly half and natural gas for a third of energy consumption in the commercial sector in IEA-11 countries in 1998. In China, the fuel mix reflects historical reliance on centralized district heating and coal boilers as well as grater availability of coal.

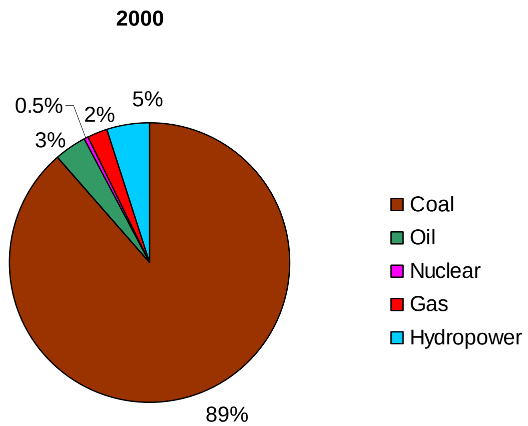


Figure 10 Commercial Primary Energy Consumption by Fuel

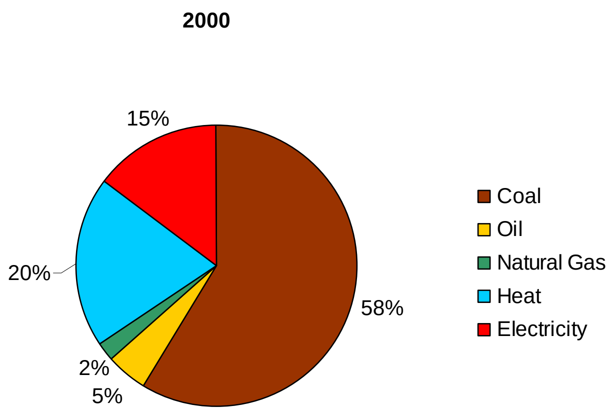


Figure 11 Commercial Final Energy Consumption by Fuel

Figure 12 shows the energy use by end use. Space heating is clearly the most important energy end use in commercial buildings. It accounted for 54% of the commercial end energy use, followed by water heating at 30%, and the two together accounted for 84% of the total in 2000. Accounting for transformation losses, the share for space heating drops to 45% and space cooling, lighting and other electric application will increase their share to 18% (Figure 13). In comparison, space heating and water heating accounted for 42.9% and 34.7% of the total final energy use respectively in Japan in 1970, which decreased to 21.5% and 21.7% respectively in 2000, while electricity use has gone up from 13.6% to 40% (IEEJ, 2003).

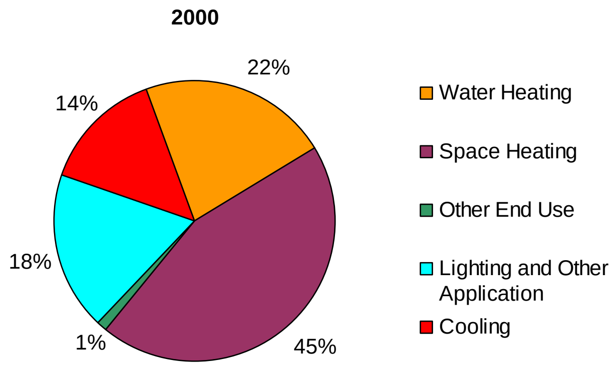


Figure 12 Commercial Primary Energy Consumption by End-use

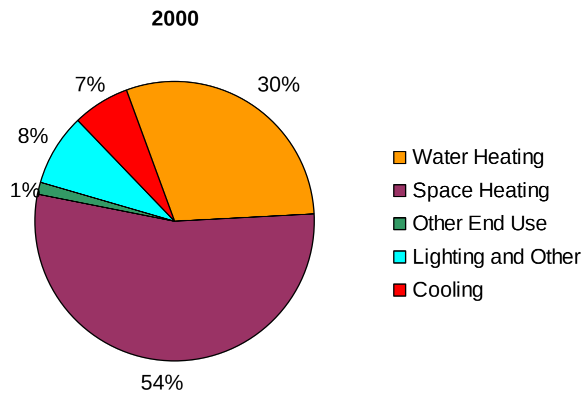


Figure 13 Commercial Final Energy Consumption by End-use

4.2.2 Key Drivers

The key driver in the commercial sector is floorspace. Time-series data on floor space are not available in the statistics for commercial buildings separately, but could be estimated by subtracting residential floor area from the total stock given in the statistic yearbook for couple of data points. Value-added GDP is not used as a direct driver to energy use but rather than a force that drives the floor area growth, because the value-added usually includes activities such as transportation and public utilities, only small part of the activity takes place in buildings (Schiper and Meyers, 1992). Although the floorspace per capita differ significantly among countries, historic trend in developed countries shows a strong correlation between the floorspace and service GDP across time (IEA, 2004). Similar trend could also be observed in Chinese commercial sector (Figure 14). In China, commercial floor area has increased at a relatively steady level, with AGR of 6%. From 1985 to 2002, the elasticity of commercial floor area to VAGDP is 0.8.

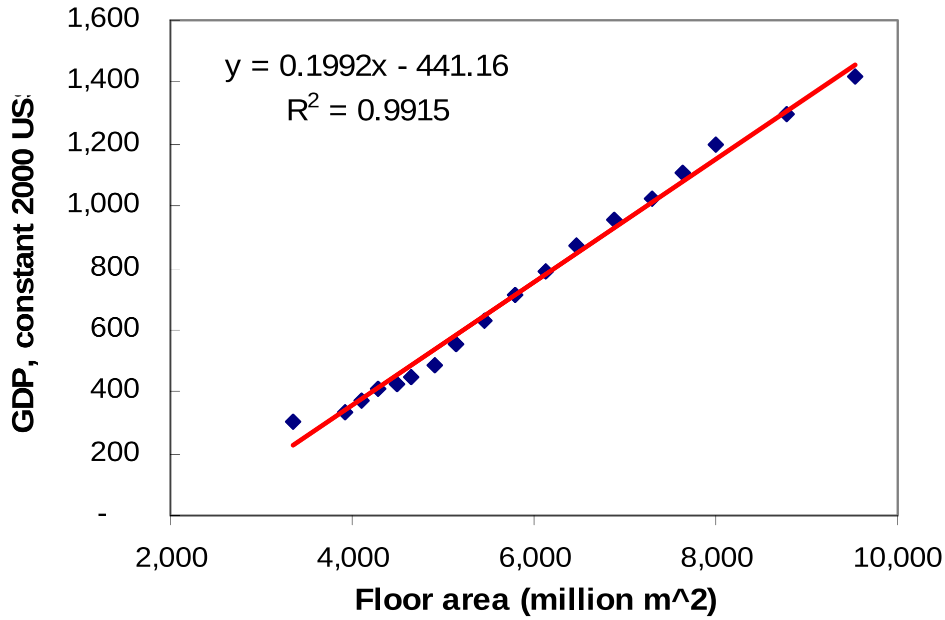


Figure 14 Commercial Floor Area and Value-added GDP, 1985-2002

Energy intensity of commercial buildings is dependent upon both the building construction as well as the energy-using activities within the building. The type of building occupant clearly influences commercial building energy use because some buildings, such as hospitals and hotels, use energy continuously while others range from sporadic use (sports and entertainment facilities) to steady weekly use (office buildings) (IEA, 1997d). Figure 15 illustrates the distributions of prototypical buildings. In the major building types, office building has the biggest share, accounting for 33%, followed by educational building, hotel and retail.

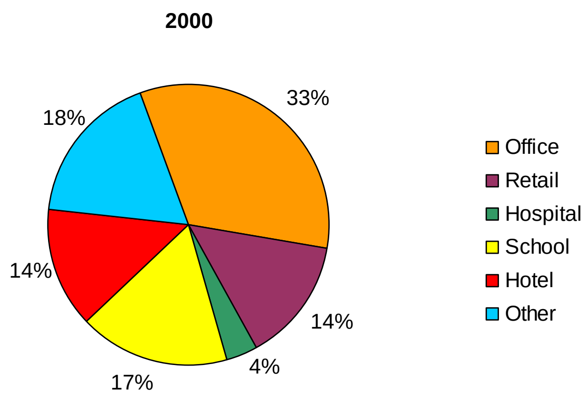


Figure 15 Floor Area Distribution

4.2.3 End Use Penetration and Intensities

Energy intensity trends in building space conditioning are affected by climate, building thermal integrity, and the heating and cooling equipment used. Space heating is an important end-use in the industrialized countries, and in some developing countries (Nadel et al., 1997).

Table 8 shows the penetration and intensity of the key end uses. Heating penetration in commercial building in China is 35% in 1998 (source). Historically, the heating zone was limited to northern China; in recent years, however, there is a continuous trend to be expanded to many southern regions. In Shanghai, 38% of the households use an electric heater for space heating in 1999 (Brockett, 2003). District heating alone in 2004 has supplied about 25% of the total area[9], while in some northern cities it has reached 90%.

Similarly, not all buildings and floor areas are air-conditioned, particularly for the old buildings, and particular type of building such as hospitals and schools. The penetration rate for space cooling will increase significantly as the demands grow along with the economy develops.

Table 8 End Use Penetration and Intensities

Drivers	End Use	unit	Office	Retail	Hospital	School	Hotel	Other
penetration	cooling		20%	31%	20%	7%	31%	20%
	space heating				35%			
Intensity	Lighting and Other App	kWH per m^2	5.2	22	8	4.1	22	5.2
	Water Heating	kWH per m^2	1.9	18.7	65	1.9	65	1.9
	Space Heating	kWH per m^2	90	70	80	70	70	80
	Cooling	kWH per m^2	40	86	50	30	70	40

Source: Zhou,2003

4.2.4 Technologies

Energy technologies may play an important role in accelerating energy improvement. Although consumer choice follows the market criteria of cost, performance and other factors (such as accessibility and availability), government can influence the introduction of technologies with measures such as incentives, subsidies, and standards Energy efficiency improvements are vital to the sustained use of all energy technology, but nowhere are they more important than for end use technologies. Particularly in developing countries, the choice of the new, more efficient technology is important because the diffusion rate could make a huge difference in future stocks (WEC, 2004).

Figure 16 and Figure 17 show an example of technology share of space heating and cooling in office building in 2000. Most of the heating technology is coal boilers, followed by district heating with a share of 28%, which all use coal as primary resource. For cooling, centralized AC accounts for 64%, and room AC for 32%. Although geothermal AC has higher efficiency, the share is insignificant. The average efficiencies of these technologies are still low in 2000 compared with that of many developed countries (Table 9). Equipment used in buildings space heating and cooling equipment, lighting and so forth- has shorter lifetime compared with the building stocks. There is a significant opportunity to replace it with more efficient equipment and systems.

[9] According to *2005 China Heat Supply Industry Annual Report*, 2005. State Information Center.

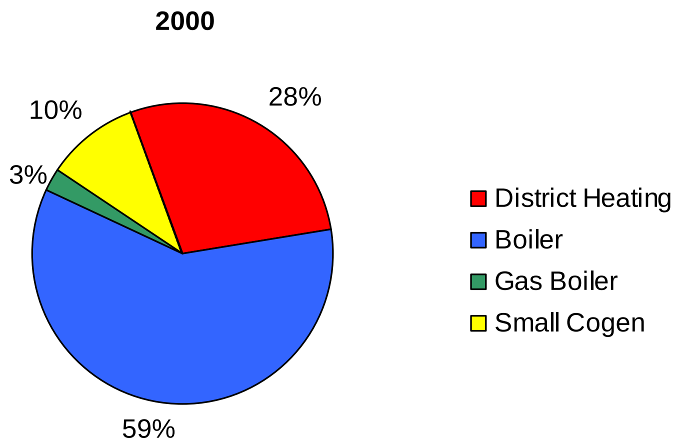


Figure 16 Space Heating Technologies

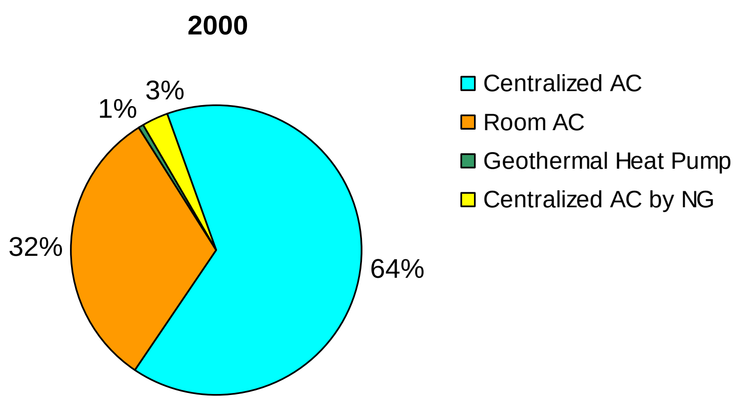


Figure 17 Space Cooling Technologies

Table 9 Technology Efficiencies

End Use	Technology	Efficiency
Space heating	District Heating	65%
	Boiler	55%
	Gas Boiler	70%
	Small Cogen	60%
	Electric Heater	90%
	Stove	10%
	Heat Pump	COP=1.8
Space Cooling	Centralized AC	COP=1.8
	Room AC	COP=2.5
	Geothermal Heat Pump	COP=3
	Centralized AC by NG	COP=1.2

4.3 Industry Sector

4.3.1 Industry Energy Consumption by Fuel and sub-sector

In 2000, China's industrial sector energy consumption was 24.54 EJ, accounting for 61% of total energy consumption. Industrial energy use is predominately coal, with 75% in 2000, and followed by oil at 15% which includes oil used as feed stock (Figure 18). Sub-sectorwise, the 7 major industries account for more than half of total industry energy use (Figure 19). Among them, the iron and steel and cement industries are the biggest energy guzzlers, account for 15% and 14% of the total, respectively. In 2006, National Development and Reform Commission (NDRC) initiated a comprehensive national program entitled "Monitoring and Guiding of Energy Efficiency Improvement of Top 1000 Energy-Consuming Enterprises in China", in which 1008 top energy-consuming enterprises have been identified and asked to improve their energy efficiency with the goal of saving 100 Mtce (2.93EJ) by 2010. The highly energy-intensive industries that are included in China's "Top 1000 Enterprises" make up about 47.5% of total industrial energy consumption (Figure 20).

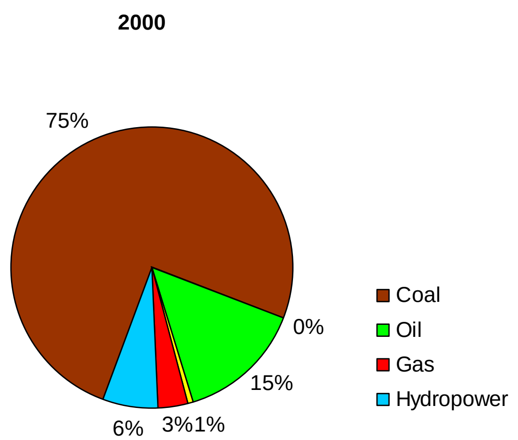


Figure 18 Industry Energy Consumption by Fuel

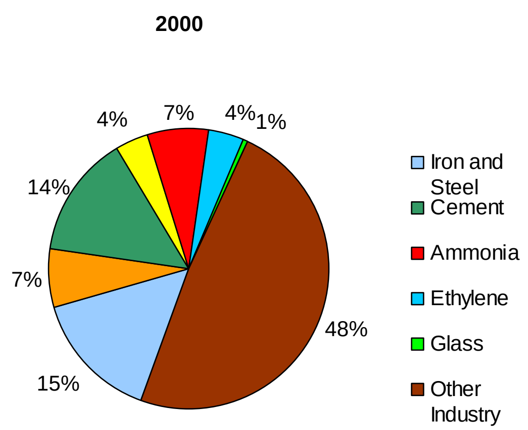


Figure 19 Industry Energy Consumption by Sub-Sectors

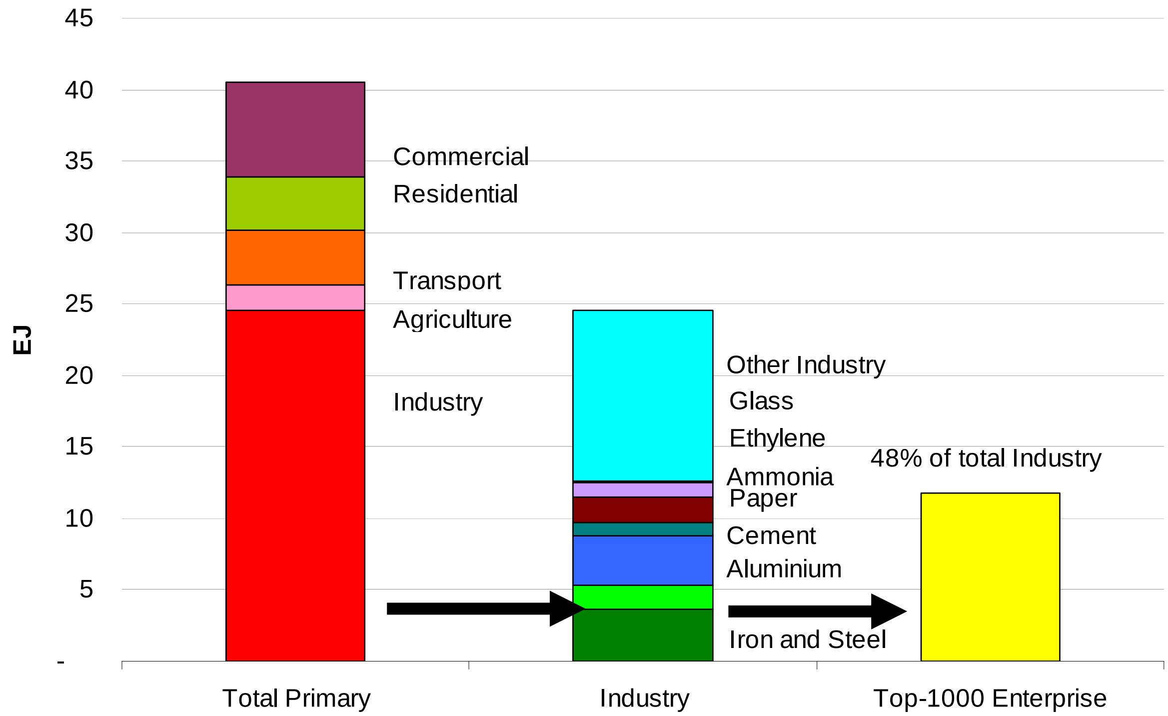


Figure 20 Industry is still the dominant energy-consuming sector in China and 7 major industries ac-count for more than half of total industrial energy use

4.3.2 Industrial Value-added GDP and Production

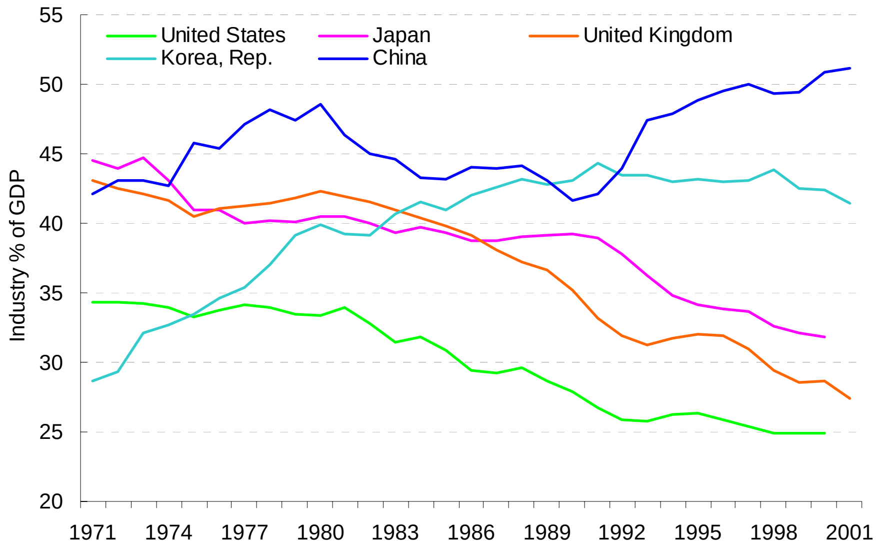
The dominance of the industrial sector in China is not surprising, since industrial energy intensity (energy use per GDP) is not only much higher than that of the other two sectors, but also because industry remains the largest sector in the Chinese economy. After 25 years of rapid industrialization, the industrial share of GDP continues to increase, while the share of the tertiary (service) sector remains flat at 40% from 1971 to 2001 (Figure 21). The service sector share in China is not only much lower than developed countries but also lower than other developing countries. For example, India's service sector comprised about 54% of the economy in 2005, while in the US, the share reached 76.5% in 2003 (World Bank, 2006). If the share of the service industry in China reached the Indian or US levels, China's energy intensity would drop 22% and 31%, respectively. While it may be difficult to boost the share of service industries in China to the levels in India or the U.S., structural shifts in the Chinese economy could nonetheless eventually contribute significantly towards the China's energy consumption reduction target for energy intensity.

The industrial sector is dominated by the production of a few major energy-intensive commodities such as steel, paper, cement, and chemicals. In any given country or region, production of these basic commodities follows the general development of the overall economy. Rapidly industrializing countries will have higher demands for infrastructure materials and more mature markets will have declining or stable consumption levels. In 2005, China was the world leader in the production of cement with 45% of the world's cement production, in the production of iron and steel with 35% and in the production of aluminum with 23% of world production (USGS, 2007).

For the major energy intensive sub-sectors, the assumptions are production-driven. Historical production data were obtained from China's statistical yearbooks (NBS, 1985-2005). In the 10^{th} five year plan, the government projected or set the target for industrial production from 2000 to 2005. However based on the actual data, the production in major industrial sectors in 2005 exceeded the original target by 50% on average (Table 10). The numbers are shown below:

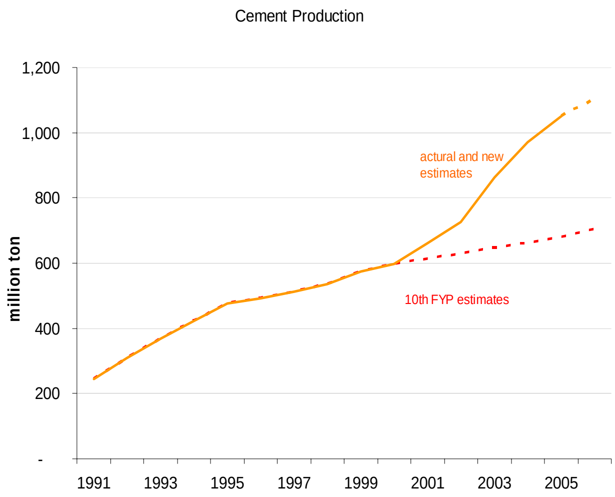
- Cement: exceeds target by 54%,
- Iron and Steel: exceeds target by 40%.
- Glass: production exceeds target by 82.3%
- Ethylene: no change
- Ammonia: production exceeds target by 28%
- Paper: production exceeds target by 31.5%
- Aluminum: production exceeds target by 92.5%

According to these developments, many industrial associations have revised their new production projection to 2010. Figure 22 provides examples in the iron and steel industry and in the cement industry.



Source: WB, 2003 and CSY, 2005

Figure 21 Share of Industry in GDP



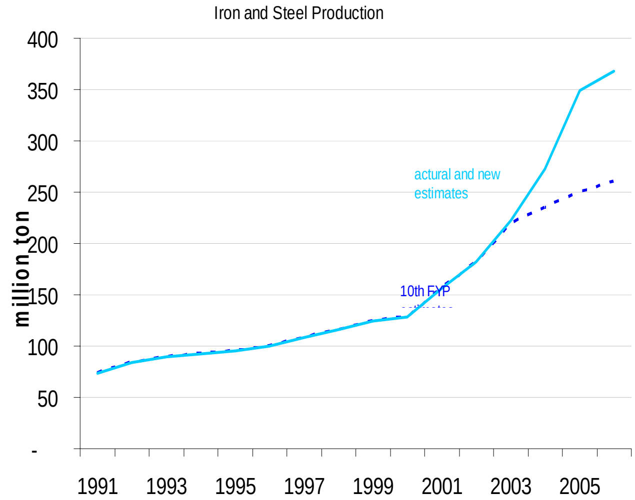


Figure 22 Estimated and Actual Production in Cement and Iron Steel Industry, 1991-2005

Table 10 Estimated and Actual Production in Major 7 Industrial Sectors

	2000	2005 estimated	2005 actual	gap
Glass	9.1	9.6	17.5	82.3%
Ethylene	4.7	7.7	NA	
Ammonia	33.6	36.0	46.0	27,8%
Paper	30.5	40.0	52.6	31.5%
Cement	597.0	680.0	1050.0	54.4%
Aluminum	3.0	4.0	7.7	92.5%
Iron and Steel	128.5	250.0	349.4	39.8%

4.3.3 Energy Intensity and Structural Shift Trends

Energy intensity in the industrial sector can be measured using both economic and physical indices. Economic energy intensity measurements (e.g. energy use/economic output) are useful for characterizing the entire industrial sector or for those portions of the industrial sector that are not easily measured in physical terms. Physical energy intensity measurements (e.g. energy use/tonne of product), also called specific energy consumption, more accurately reflect trends in energy efficiency, but are typically limited to use in the energy-intensive industrial sub-sectors. Evaluation of these two means of measuring energy intensity have shown that economic energy intensity values do not always accurately reflect physical energy intensity trends, making physical energy intensity measurements the preferred metric where possible (Worrell et al., 1997b; Freeman et al., 1996).

Figure 23 presents energy intensity trends in China by three main sectors as defined by China's statistical administration: primary (agriculture), secondary (industry and construction), and tertiary (transportation, telecommunications, post, and retail). The GDP values are the revised figures (NBS, 2005), adjusted to 2000 price. It can be seen that energy intensity for the secondary sector is much higher than that for the primary and tertiary sectors. The trend in aggregate energy intensity mirrors closely that for the industrial sector with both showing a rebound in energy use per unit of GDP after 2001, after steady declines since the mid-1990s.

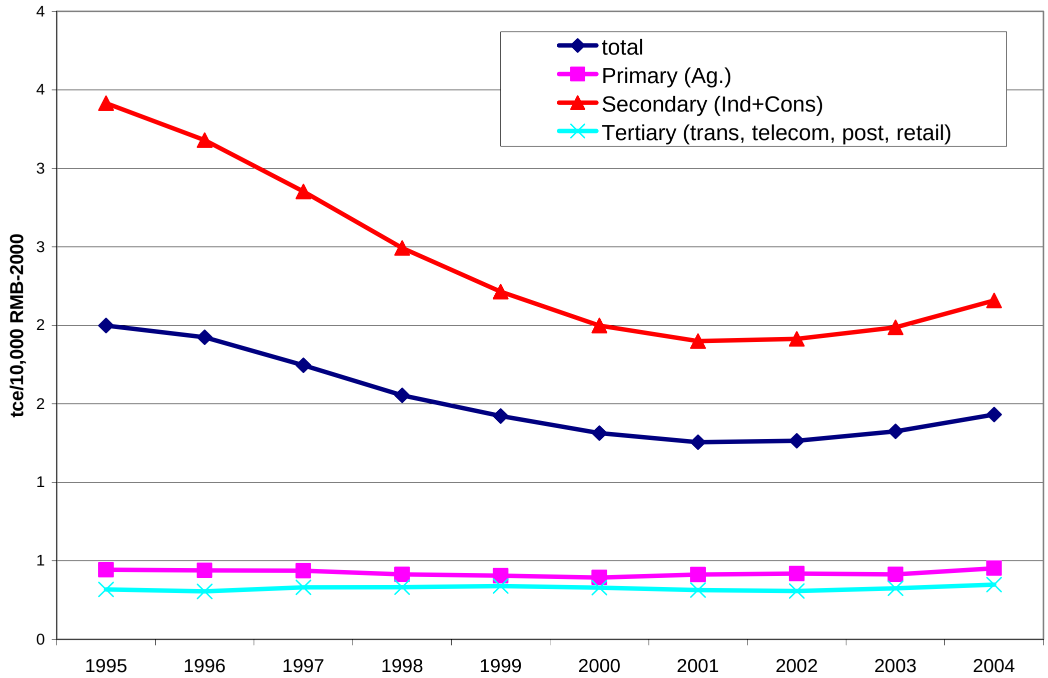


Figure 23 Energy intensity trends in China by three main sectors, 1995 to 2004

Reduction of energy intensity is closely linked to the definition of structure, structural change, and efficiency improvement. Decomposition analysis is used to distinguish the effects of structural change and efficiency improvement. Structural change can be broken down into intra-sectoral (e.g. a shift towards more recycled steel), inter-sectoral (e.g. a shift from steel to aluminum within the basic metals industry)..In this section, the results of a decomposition analysis of energy intensity trends are discussed to identify the relative contributions of shifts in economic structure and changing efficiency of energy use (Lin,2006)

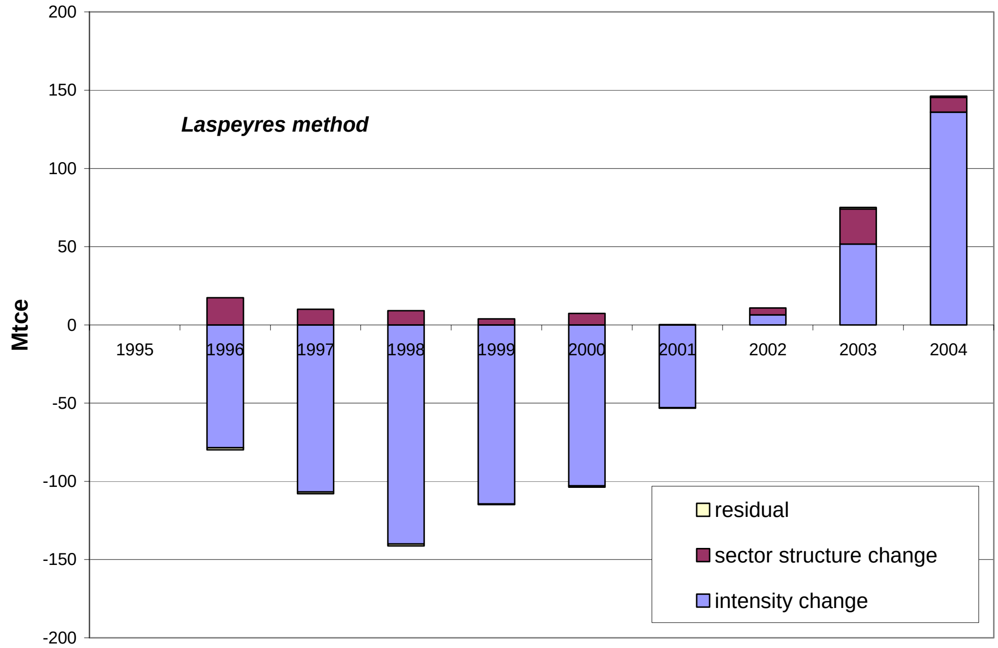


Figure 24 Inter-Sector Structural Change Versus Energy Intensity Change

We first apply this methodology to aggregate data using only three sectors: the primary, the secondary, and the tertiary. Figure 24 illustrates the results of this analysis, showing the change in energy use due to inter-sector structural change and energy intensity change for each year.

It can be seen that energy intensity reduction within each sector was the dominant factor driving the decline in energy use in the late 1990's, leading to a drop in total energy intensity. However, since 2002, total energy intensity increased mostly due to the rebound in industry energy intensity (as shown previously in Figure 23). This rebound effect is particularly strong for 2003 and 2004.

Structural shift among the three sectors has always had a small positive effect on total energy intensity, that is, a growing share of the industrial sector tends to cause total energy intensity to increase, other things being equal.

At the first glance, these results are counter-intuitive. In a rapidly expanding economy, new and more efficient technologies are typically deployed throughout the economy, which should lead to a reduction in energy intensity in industries. However, industrial energy intensity is determined by two factors: 1) energy efficiency in industrial sub-sectors, 2) the relative outputs of the sub-sectors. Thus, it is possible that overall industrial energy intensity would increase, even when energy intensities at the sub-sectors are declining because the relative outputs of energy intensive sub-sectors such as cement and iron and steel are rising.

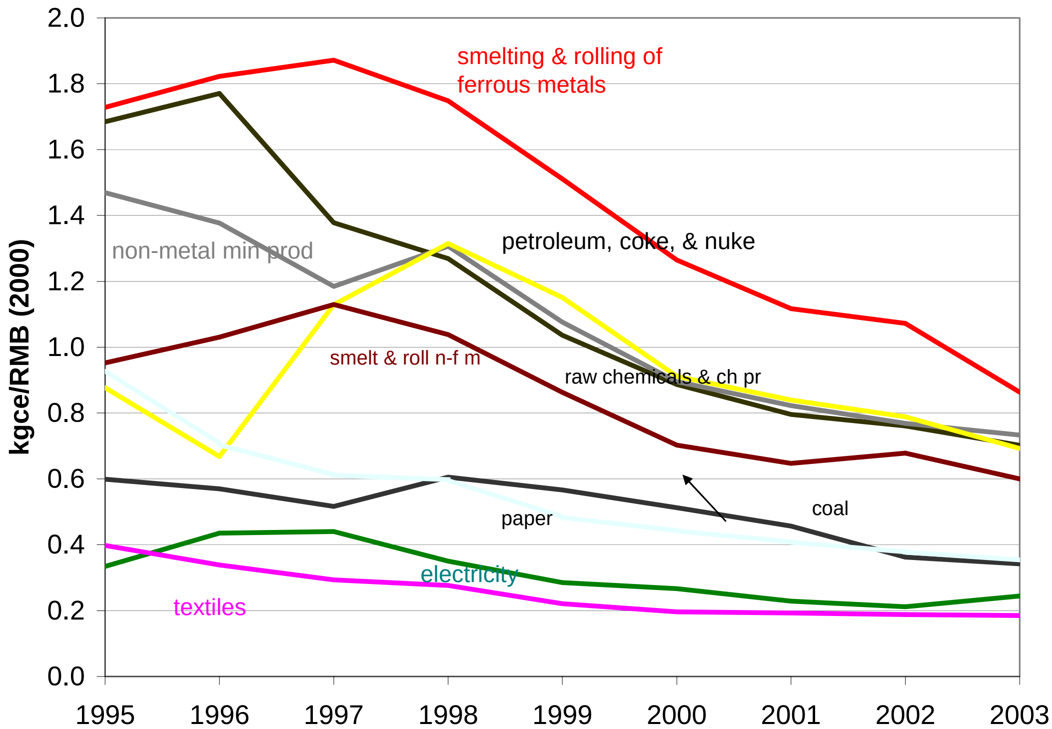


Figure 25 Energy intensities for major industry sub-sectors in China.

Figure 25 shows that for nine major energy-intensive industries, energy intensities have declined steadily since the mid-1990s, with the exception of the electricity generation industry. This exception is likely to be caused by the heavy use of small and thus less efficient generators in the last few years when there are widespread electricity shortages, and the fact the margins could be eroding in the electric generation industry, since the tariff has been held artificially low while fuel prices have gone up tremendously.

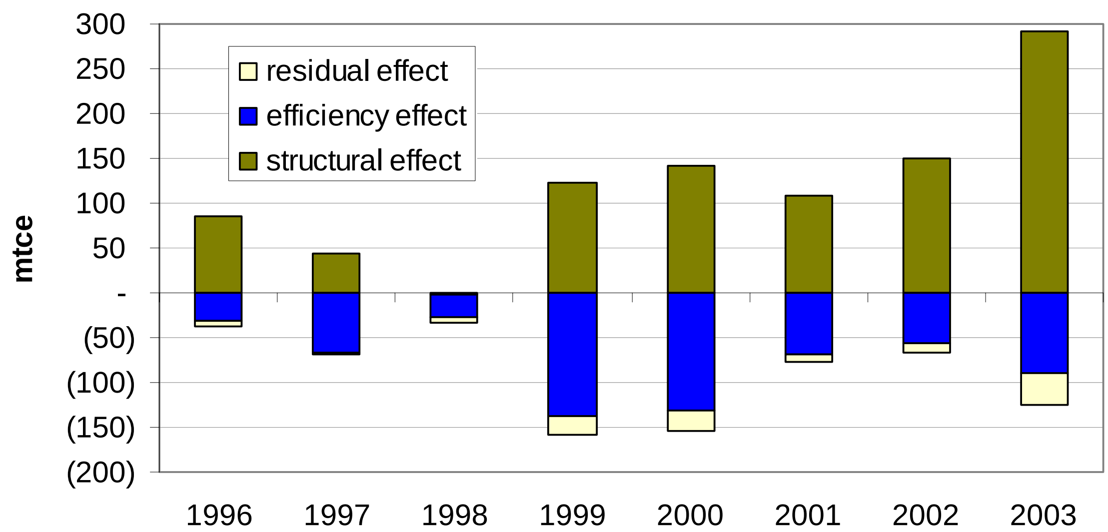


Figure 26 Effect of efficiency changes and structural shift among industry sub-sectors

Further analysis of the effect of efficiency changes and structural shifts among the nine industrial sub-sectors shows that from 1996 to 2003 there was steady efficiency improvement; however, the pace of efficiency gains slowed down somewhat since 2000 (see Figure 26).

In the meantime, the effect of structural shifts within industrial sub-sectors – rapid growth in cement and steel productions - increased in recent years, and since 2001 has overwhelmed the effect of efficiency gains. As a result, the overall energy intensity of industries is higher today.

Changes in energy intensities can also be disaggregated into structural changes and efficiency improvements at the sub-sector level. Although China has reduced its energy intensity for most of the industrial sub-sectors over the years, the comparison with international level indicates that much more effort can be made in the future (Table 11)

Table 11 Comparison of Industry Energy Intensity between China and International

Item	Unit	China	International
Comparable Energy consumption for Steel	kgce/ton	726 (2003)	646 (2003 Japan)
Energy Consumption for Ethylene	kgce/ton	890 (2003)	629 (2003 Japan)
Energy Consumption for Synthetic Ammonia	kgce/ton	1200 (2000)	970 (2000 US)
Energy Consumption for Cement	kgce/ton	181 (2003)	128 (2003 Japan)

4.4 Transportation Sector

4.4.1 Passenger Travel

4.4.1.1 Energy Consumption by Mode

The adjusted transportation energy consumption was 3.6 EJ in 2000, accounting for 10% of primary energy. In terms of fuel; petroleum has retained its dominance throughout the years, Gasoline, diesel and other oil account for 98% of energy use for travel.

In 2000, Passenger transport consumed 34% of the total energy use; among the modes, passenger road alone accounts for 24% of the total transport energy consumed, followed by air at 19% and rail at 14% (Figure 27 and Figure 28). Cars (including both personal cars and public cars) and taxis account for nearly half of the energy in passenger road, but only 8.3% of the total transport energy. This is significantly less than that of the developed countries, which had a share of 84% in 1998 (IEA-11, IEA,2004)

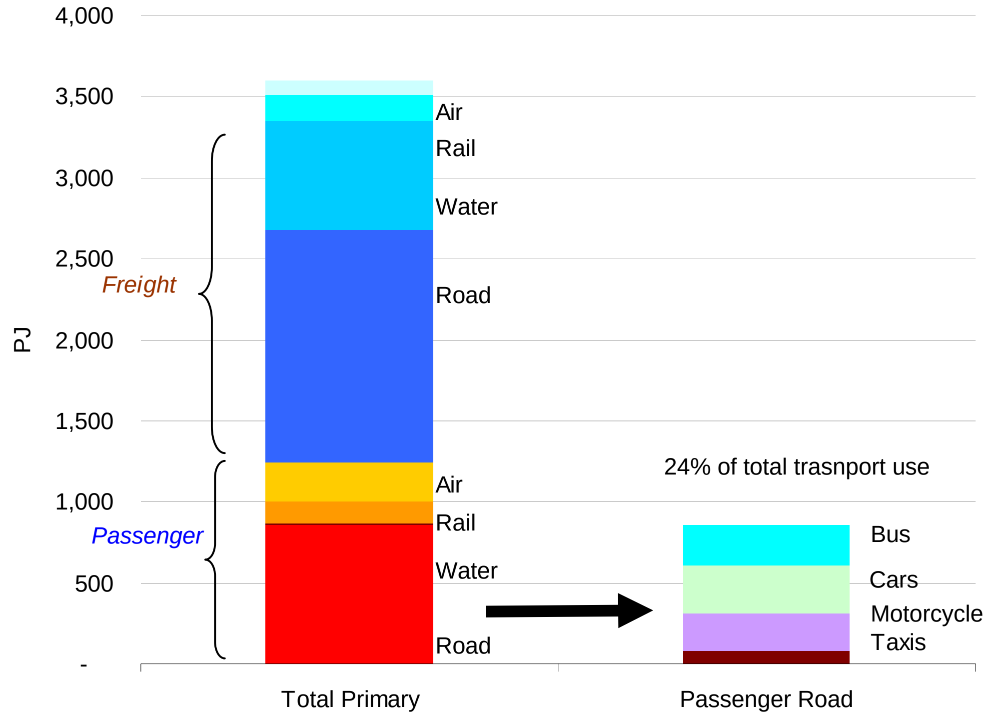


Figure 27 Transport Energy Consumption by Mode

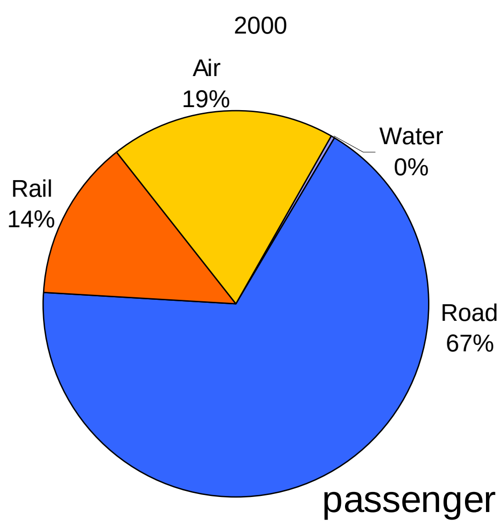


Figure 28 Passenger Energy Use by Mode

4.4.1.2 Passenger travel by mode

Passenger-km series for rail, water, air and intercity highway road can be acquired from China Statistical Yearbooks and the Transportation Yearbooks for different years. However, such data does not exist for vehicles intra-city or intra-rural. Data on stocks and the usage pattern (such as average travel distance and the annual amount of the trips) were used to calculate the total turnover[10].

[10] Usage pattern derived from ERI (2003)“China Sustainable Development Energy and Carbon Emission Scenarios

Figure 29 shows the passenger-km/capita by mode from 1991 to 2002. Passenger-km in China has increased from 660.8 passenger-km/capita to 2854.9 passenger-km/capita between 1991 and 2001, increasing at an annual growth rate (AGR) of 14%, while the growth rate is only 1.0% for population. However it is still far behind the developed countries. For example, the U.S. is the highest at 25,000 kilometers per capita; even Japan where the number is the lowest in IEA countries reached 10,000 kilometers per person in 2000 (IEA,2004). The growth in each km passenger transport mode varies from -5% (water) to 18% (road). Road transport rose the fastest at 18%, followed by air at 14% and railway by 5%, while demand for water transport has actually decreased.

Among the four modes, road dominated overall passenger transport and the share has gone up from 58% in 1991 and 82% in 2000. Although rail has also increased, the share for railway has decreased from 36% to 14% during the ten years, which is not surprising. All over the world, rail transport stagnates as a result of intense competition from road transport.

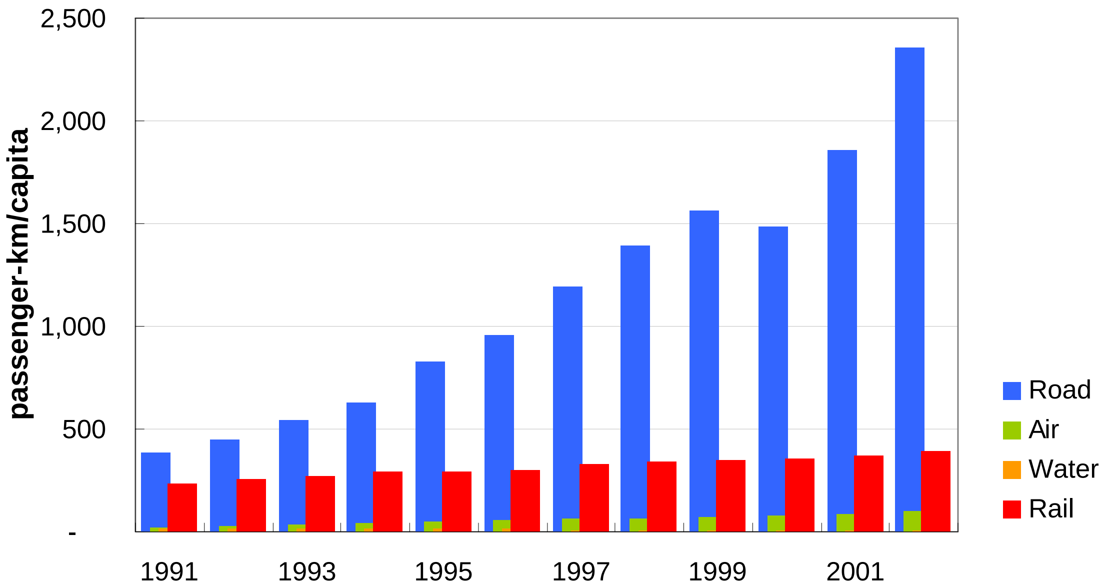


Figure 29 Passenger travel by mode (passenger-km/capita)

4.4.1.3 Vehicle Stock and Car Ownership

Total vehicle stocks were divided by registration type such as private and business, for which data could be obtained from Chinese government statistics (NBS,1985-2005). Private vehicle stock numbers were often mistreated as number of personal cars (family car); therefore the stock of personal cars in China is usually overestimated. Our investigation on the definition of this category suggests that this includes privately owned cars, mini buses and most of the taxis. Existing data on car ownership per 100 household in urban and rural, and urban taxi share were used to break the stock number down to each vehicle type

The stock of cars in our analysis is the sum of personal cars, taxis and government vehicles. Figure 30 illustrates the estimated break down of each type of car. Before 1998, almost all cars were government cars. The stock of total cars has increased from 1.42 million to 7.06 million in 2002, among the different types, the stock of personal cars has increased form 0.47 million in 1999 to 2.2 million in 2002, 4.7 times of increase in only 3 years. However, the car ownership is still 0.88 per

Analysis”

100 households in urban and 0.41 per 100 households in rural, far behind the European countries that range from 35% to 50% per capita in 1998.

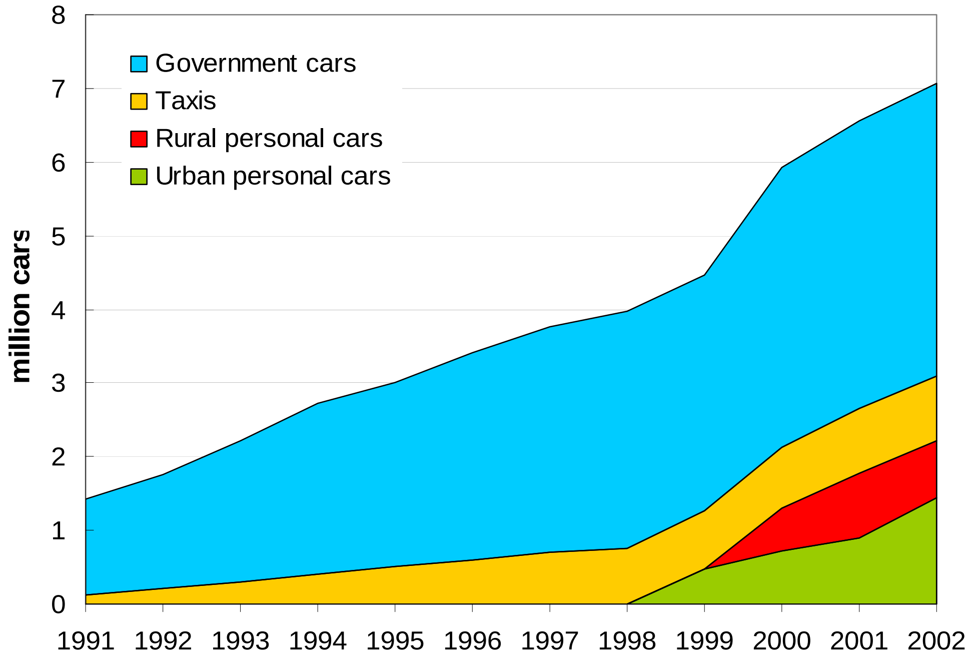
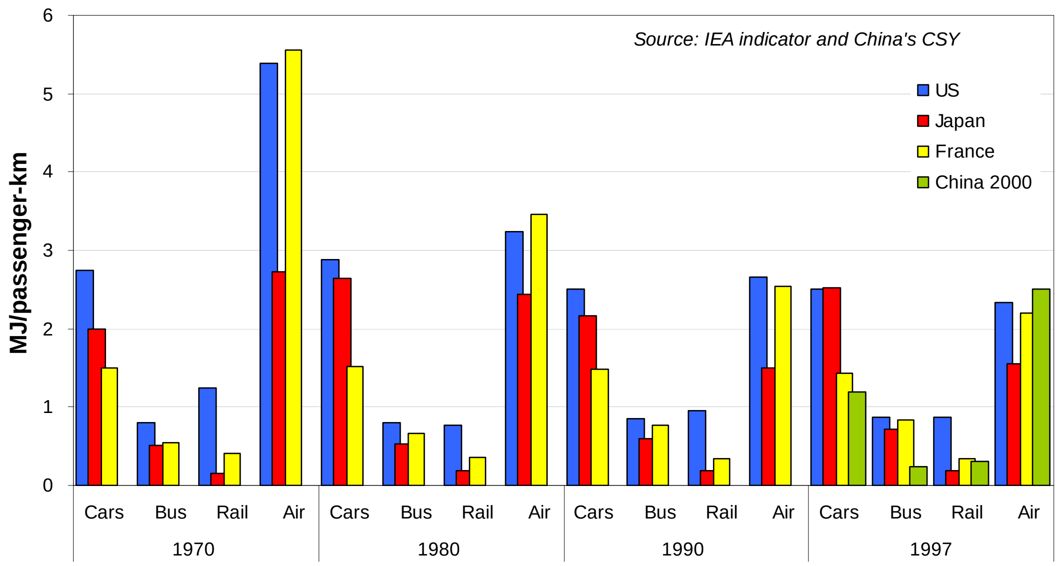


Figure 30 Car Stock by Type, 1991-2002

4.4.1.4   Energy Intensity

Experience in the developed world has shown that transport energy intensity has not declined much except for air travel (IEA, 2004). Car energy intensity only declined by about 10% across the IEA-11 countries, while almost no change can be observed for that of rail and for bus; an actual increase in energy intensity can in fact be seen. In many cases, energy efficiency improvements have been largely offset by the use of larger and heavier cars. Among the modes, bus and rail (particularly electric) appears to be the most efficient, and energy intensity in air is higher than that of cars. Figure 31 illustrates the energy intensity change by mode in the U.S., Japan and France, and its comparison with China in 2000. China turns out to be more efficient in cars and buses, which can be attributed to higher occupancy.



Source: IEA, 2004; ?

Figure 31 Passenger Energy Per Passenger-km by Mode

4.4.1.5 Car Travel distance and Occupancy

Historic trends in IEA-11 countries show that the average use of vehicles (km driven) has not risen with passenger travel and car ownership level. Vehicles in those countries are driven between 10,000 and 20,000 km per year, and car travel (passenger-km) has grown at about the same rate as car ownership. We estimated that the averaged travel distance per year per vehicle for personal cars has increased from 17,115 km in 1991 to 19,345 km in 2000, and 35,000 km for taxis across the years.

4.4.2 Freight

4.4.2.1 Energy Consumption by Mode

While passenger travel patterns are more closely related to personal wealth and lifestyle changes, freight transport activities are closely connected to overall economic activity. As economies develop, goods take on a greater share of freight transport. In 2000, freight transport consumed 66% of the total energy used in transport sector. Among the modes, road (mostly trucks) alone accounts for 59% of energy, followed by water at 27% and rail at 10% (Figure 32). This is significantly less than that of the developed countries, for which trucks held a share of 94% in 1998 (IEA-11, IEA, 2004), up from 88% in 1973. Freight road includes trucks, tractors and rural vehicles (three-wheeler and four-wheeler)

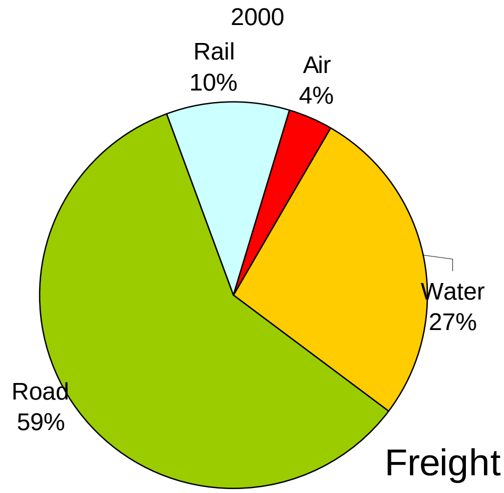


Figure 32 Freight Transport energy use by Mode

4.4.2.2 Freight transport activity

Freight transport activity, measured in tonne-km, increased between 1991 and 2002 at 4.8% annually, which is mostly attributable to the increase in road use and water use (Figure 33). There has been a shift of freight ton-km from rail to road. Road activity enjoyed an increase of share with from 28.9% to 32.7%. In absolute terms, it increased from 616 billion tonne-km to 1,164 billion ton-km from 1991 to 2002, an increase of 189%.

As observed in passenger transport, the rail sector has experienced reduction in share from 51.5% to 42.6%. The annual growth rate for road and rail is 6% vs. 3%. Due to the decline of rail activity, the share of water-borne freight energy has also increased from 19.5% to 24.5%. Within water-borne freight, coastal water has accounted for 72% in 1991 and 79% in 2002, while for air, international travel has been slightly larger than domestic, although its share declined from 59% to 55%.The increase in the role of trucks reflects freight toward products for which trucks have inherent advantages over competing modes, and the trend observed in China is consistent with experience in other countries (Schipper and Merers, 1992).

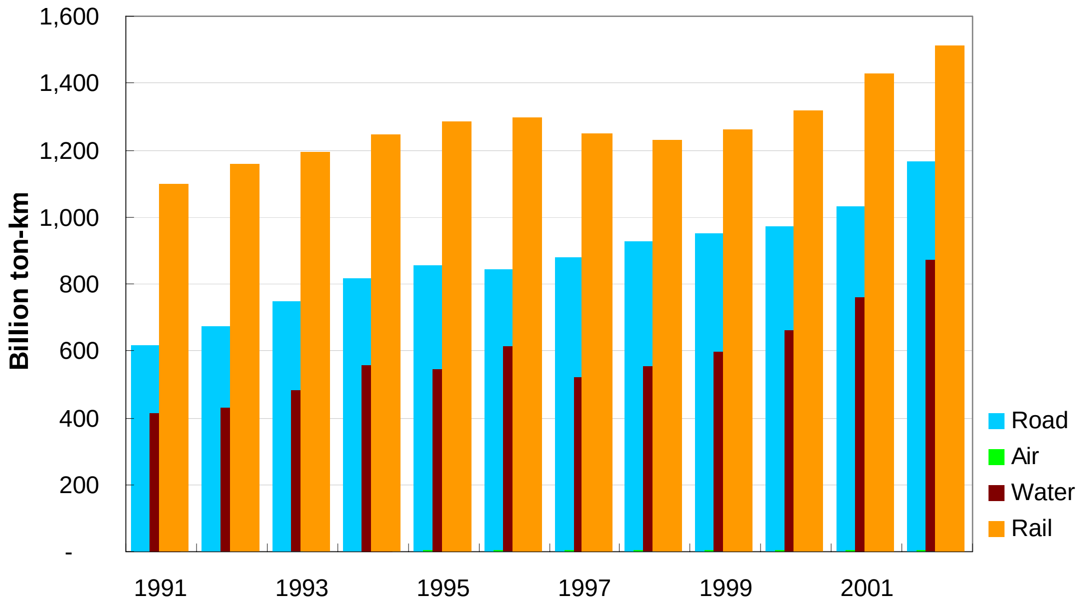


Figure 33 Freight Transport Ton-km per Capita trend

4.4.2.3 Intensity

The aggregate energy intensity for freight in the developed world has been remarkably stable, indicating that freight transport is not becoming less energy intensive across countries (IEA, 2004). However energy intensity by each mode has declined except for road (Figure 34). The aggregated intensity for trucks is 1.55 MJ per tonne-km, compared with that of 2.91 MJ in the U.S. and 4.02 MJ in Japan (IEA, 2004). The variation reflects differences in the average size of vehicle and average load factor. Japan which has short-hauls and small trucks turns out to be at the high end. China, where the trucks are usually overloaded ends up being efficient in terms of MJ consumed per ton-km.

On average, it requires four to eight times more energy to move a tonne of goods one kilometer by air than by truck. Further, trucks use eleven to thirteen times more energy than rail to move the same amount of goods. The figure also indicates that mode shifting from truck to rail or water can have a big impact on energy use, and the energy intensity reduction in rail and water are not as important as for trucks.

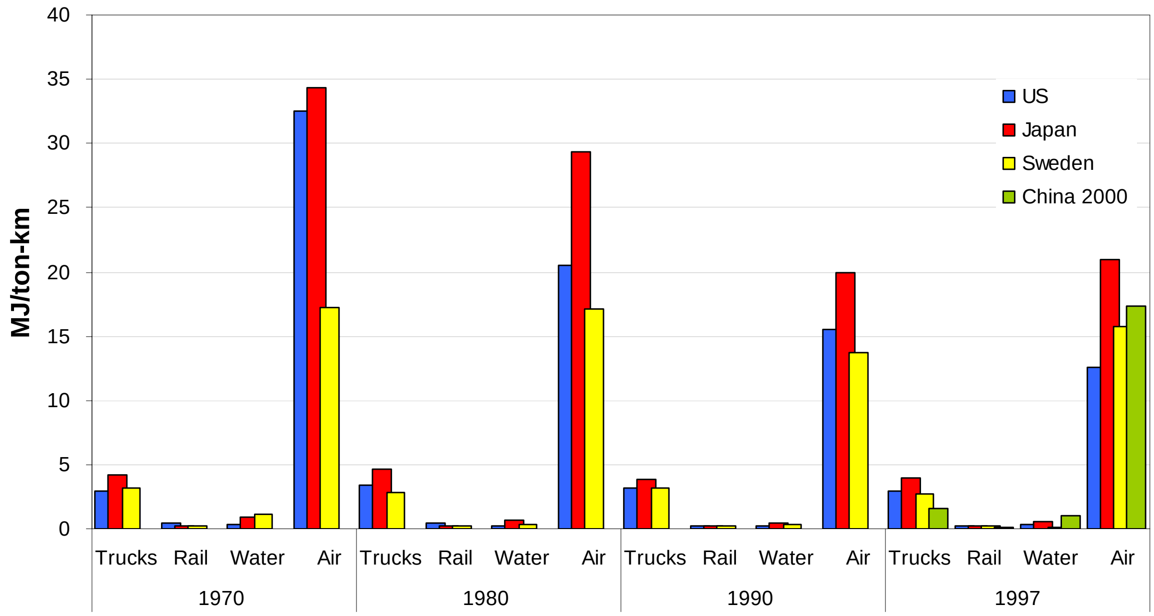


Figure 34 Intensity by Mode

4.4.2.4 Truck Load Factor and Distance

The number of trips or distance traveled increases with the industrial and agricultural output, which is linked to the economic development. The average distance traveled per truck per year in China is 42,444 km per year and the average carried tonnage is 4.22 tonne (Table 12) (He,2005)

Table 12 Average truck load (tons)

	Average traveled Distance	Average Load
Average Tonnage of Heavy Duty Trucks	56,900 km	15
Average Tonnage of Medium Duty Trucks	56,900 km	6
Average Tonnage of Light Duty Trucks	35,000 km	3
Average Tonnage of Minitrucks	35,000 km	1.8

5. Future outlook for Energy Use in China: (8 pages)

5.1 Activity and structural change

5.1.1 Population and Urbanization

The number of people living in urban areas in China increased between 1980 and 2000, growing from 193 million, or 19.5% of the total in 1970 to 451.8 million, or 35.6% of total in 2000 and is projected to increase to 55.8% in 2020 (UN, 2004) (see Figure 35). On the other hand, total population will still grow, but at a much slower pace compared with that of years pre 2000, at 0.5% per year. Increasing urbanization leads to the increased use of commercial fuels, such as natural gas and liquefied petroleum gas, for cooking instead of traditional biomass fuels. Additional increases in energy use come with electrification, when appliances and lighting are adopted. In general, higher levels of urbanization are associated with higher incomes and increased household energy use (Sathaye et al., 1989; Nadel et al., 1997).

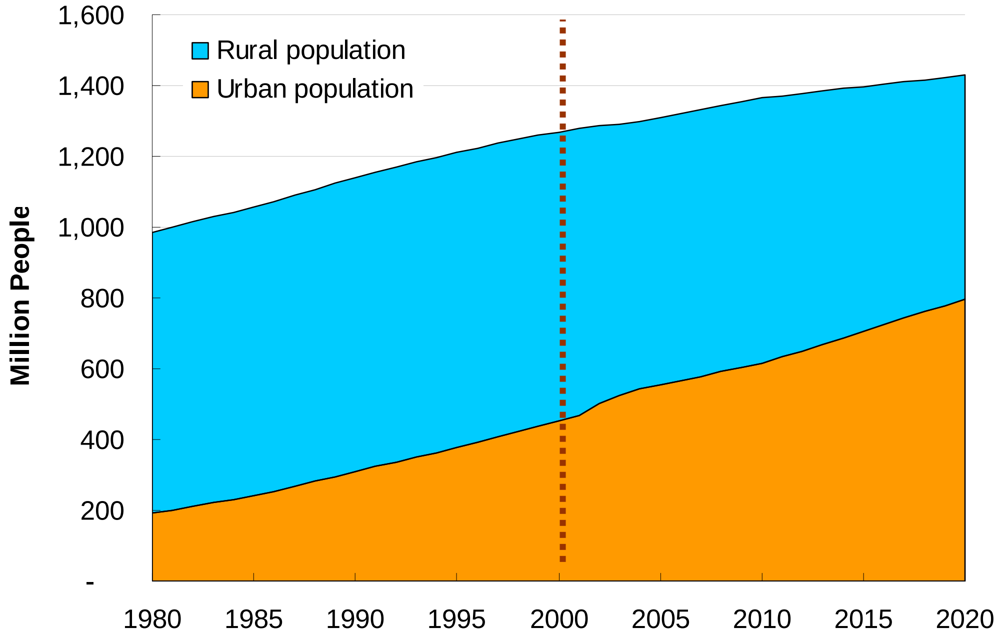


Figure 35 Population Trends and Projection

5.1.2 Residential Living Area and Household Size

Globally, the size of the household tends to decline with increasing income and urbanization of the population. In the case of China, the "one child policy" enforced such a decline particularly rigorously. Average household size in China dropped from 5.2 persons per household in 1981 to 3.04 persons per household in 2002 (Figure 36). And this trend is expected to continue, with urban household size decreasing from 3.13 persons/household in 2000 to 2.88 persons/household in 2020, the level of Japanese household size today. It is also assumed that rural household size will be 3.9 persons/household in 2020.

In developed countries, the amount of household floor space per person has been gradually increasing since at least the early 1970s. In China, floor space per person increased from 9.9m^2 to 19.8 m^2 in urban and from 17.8m^2 to 24.8 m^2, from 1990 to 2000. In 2030, it is assumed to be equal to the current size in Japanese households (30 m^2/capita) while rural residences will have 34.8 m^2/capita).
The decline in household size leads to an increase in the total number of households in the region, which, together with the increase in living area will multiply the contribution of energy demand from households.

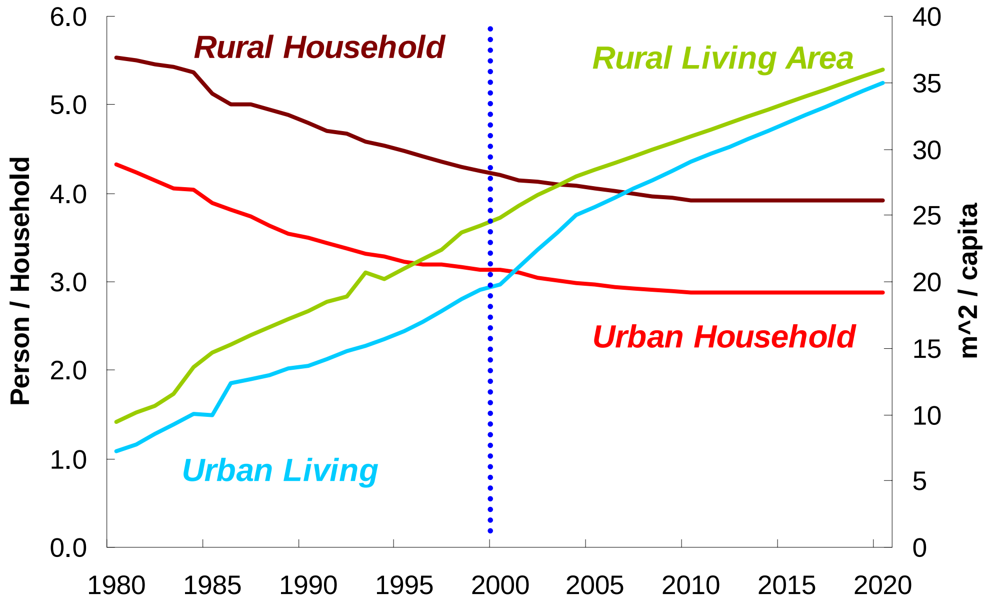


Figure 36 Floor area per Capita and Household Size Trend and Projection

5.1.3 Residential Appliance Penetration Change

Ownership of the four major electric appliances-refrigerators, air conditioners, clothes washers and TVs- increased significantly from 1981 to 2000 except for black & white TVs. For example, refrigerator ownership started at 1% in 1981 and increased to 80.1% in 2000 in urban China. Increased income levels and decreasing appliance prices drive the growth of the ownership of appliances, but will slow down when reaches a high saturation rate. In urban areas, color TV is already universal; clothes washer ownership is approaching saturation; and refrigerator rates are also growing. All of these will result in a much slower pace of growth of appliance ownership through 2020, and therefore will have much smaller impact on household electricity consumption in the future. Other factors such as air conditioning is an exception because it began to appear in early 90s, and is expected continue growing much faster. Japan is used as a proxy to project the development of China. The level of energy required for urban households in China in 2020 is assumed to be similar to that consumed in urban households in Japan today. For appliance saturation, it is assumed that urban Chinese households will reach the level of appliance ownership of Japan today by 2020. (Figure 37 and Figure 38).

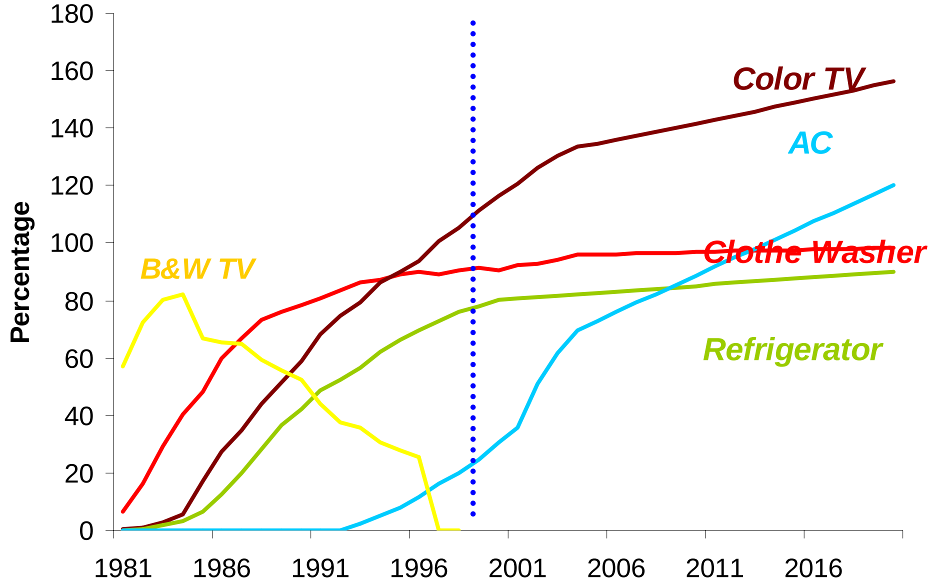


Figure 37 Urban Appliance Ownership

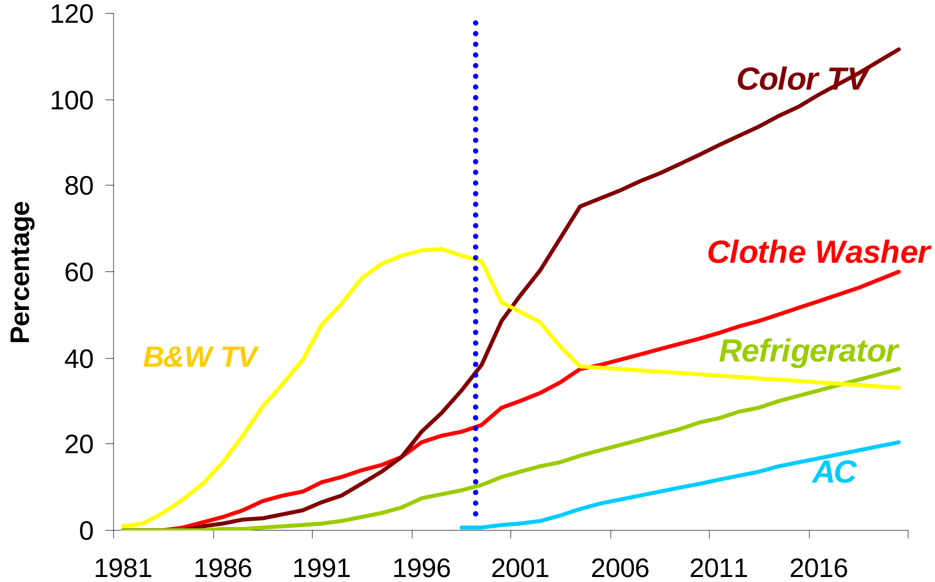


Figure 38 Rural Appliance Ownership

5.1.4 Commercial Floor Space Change

The key driver in the commercial sector is the floor space. Historic trends in developed countries show a strong correlation between commercial floor space and service GDP across time (IEA, 2004). In China, commercial floor space has increased at a relative steady level, with an AGR of 6%. The elasticity of commercial floor space to GDP is 0.63 for the period between 1985 and 2000, with a higher elasticity of 0.75 in early years (1985-1989) and 0.58 for subsequent years after 2000?. The annual growth rate in our scenario indicates 0.75 (AGR 7%) to 2010 in our projection to match official 2010 floor space targets(Zhou, 2003), and 0.58 (AGR 3%) for years after 2010.That implies the commercial floor space will grow from 8,000 m2 in 2000 to 15,700 m2 in 2010, and 21,230 m^2 in 2020 (Figure 39).

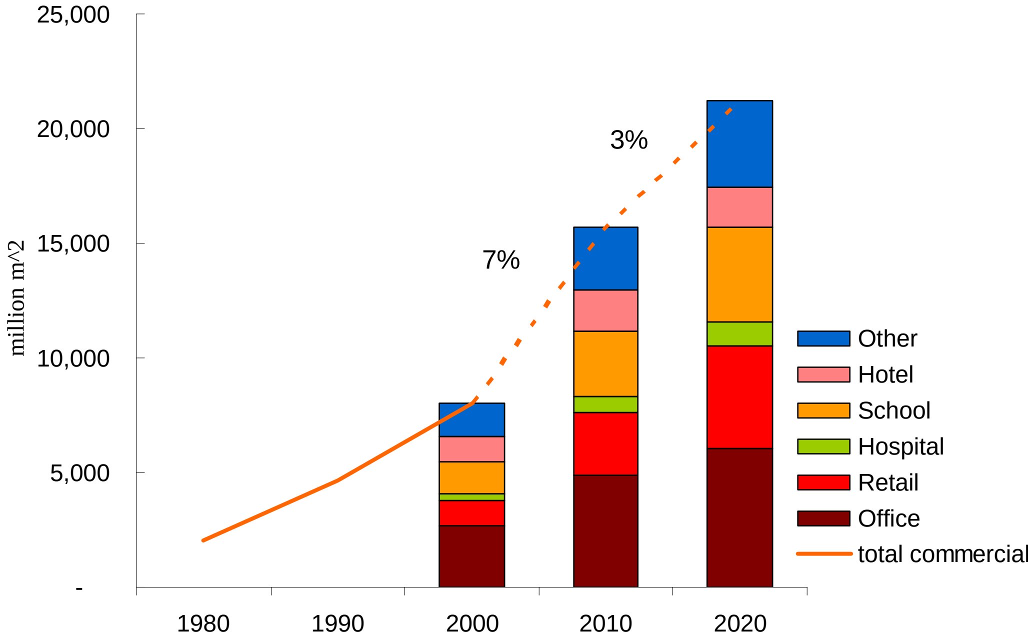


Figure 39 Commercial Floor Space Growth and the Breakdown by Type of Building

5.1.5 Commercial End Use Penetration

To meet Chinese consumers' growing demand for comfort and convenience, penetration of all major building energy end-uses will increase significantly by 2020. For space heating, it will increase from 35 percent in 2000 to 55 percent as the country's "heating zone", historically limited to northern China, continues to expand into many southern regions. Similarly, only a fraction of commercial buildings are currently air-conditioned, with very low penetration in older buildings and in hospitals and schools. We expect the penetration rate to reach 55 percent for most building types by 2020 based on qualitative objectives stated in research by China's Energy Research Institute (Zhou,2003) (Table 13)

Table 13 Penetration of Space Heating and Cooling in Commercial Buildings

		2000	2010	2020
Space Cooling	Office	20%	38%	55%
	Retail	31%	43%	55%
	Hospital	20%	35%	50%
	School	7%	24%	40%
	Hotel	31%	43%	55%
	Other	20%	38%	55%
Space Heating	All buildings	35%	45%	55%

5.1.6 Commercial Space Cooling and Heating Technologies

China's objectives have incorporated moderate measures toward adopting more efficient technologies. For space heating and water heating, the use of conventional coal boiler will be reduced significantly, while more efficient technologies such as gas boilers and heat pumps will grow faster. For space cooling, electric Central Air Conditioners (CAC) and Room Air Conditioners (RAC) will slightly reduce their share, and AC using natural gas (NG) and geothermal AC will gradually expend. Efficient lighting technologies offer the potential for energy reduction as well. State-of-the art technology includes electronic ballasts and compact fluorescent lamps (CFLs), and other measures to increase lighting-system efficiency. Figure 40 to Figure 41 show an example of end use technologies change in office building.

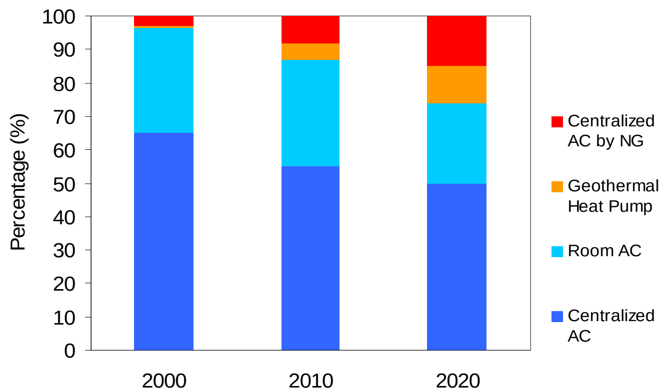


Figure 40 Space Cooling Technology Shift in Office Building

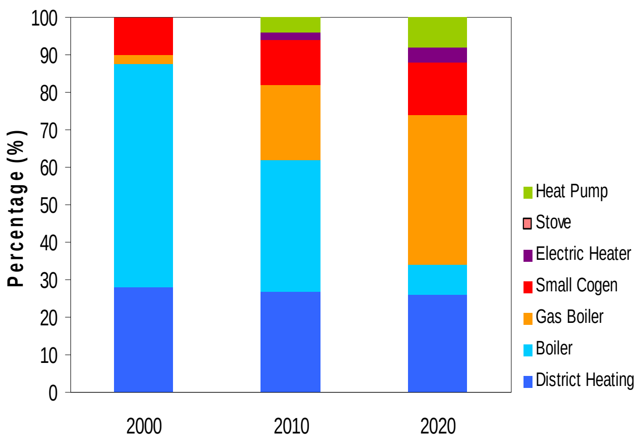


Figure 41 Space Heating Technology Shift in Office Building

5.1.7 Industry Production Projection

Production of the basic commodities follows the general development of the overall economy. Rapidly industrializing countries will have higher demands for infrastructure materials and more mature markets will have declining or stable consumption levels. China will follow the same path according to the government plan. As discussed in previous section (4.3.2), Actual production in major industrial sectors in 2005 exceeded the original target stated in 10^{th} five year plan by 50% on average. According to these developments, many industrial associations have revised their new production projections to 2010. Many of them will decline after 2010 if the 2020 target remains the same (Table 14).

Table 14 Industrial Production in Major Sub-sectors (million ton)

	2000	2005	2010	2020	00-05	05-10	10-20
Glass	9.1	17.5	27.5	10.1	14.0%	9.5%	-9.5%
Ethylene	4.7	7.6	13.0	20.0	10.1%	11.3%	4.4%
Ammonia	33.6	46.0	46.0	44.0	6.5%	0.0%	-0.4%
Paper	30.5	52.6	68.0	75.0	11.5%	5.3%	1.0%
Cement	597.0	1050.0	1310.0	1310.0	12.0%	4.5%	0.0%
Aluminium	3.0	7.7	11.2	19.2	20.7%	7.8%	5.5%
Iron and Steel	128.5	349.4	440.0	440.0	22.1%	4.7%	0.0%

Source: industry associations, NDRC

5.1.8 Passenger-km by Mode Change

Future vehicle stock and turnover (pass-km or ton-km) projections were based on the assumption that the high growth rates in most vehicle classes will be sustained through 2005, after which the growth rates will begin to decrease in steps 2005-2010, 2011-2015,and finally stabilize at the rates chosen for 2015-2020. Assumptions from World Energy Council's and ERI were used in addition to guide the growth of the respective modes (Chen, 1998. ERI,2003).

Passenger-km in China will continue to increase from 2449.4 billion passenger-kilometers (BPkm) to 11152 BPkm from 2000 to 2020, at an annual growth rate (AGR) of 7.9% (Figure 42). Air transport will rise the fastest at 9.3%, followed by Road at 8.5% and Railway by 3.3%, demand for water transport will remain at the same level as 2000. Among the four modes, road dominates overall passenger transport with a share of 77% in 2000, growing to 87% in 2020. Although rail energy use increases, the share for railway will decline from 19% to 8% during the 20 years. Although a large proportion of passenger mobility will still be catered to by buses, the share of buses in road transport will decrease from 56% to 42%. The use of cars will increase from 13% to 35%, and motorcycles (two wheelers) will decrease from 27% to 20%..

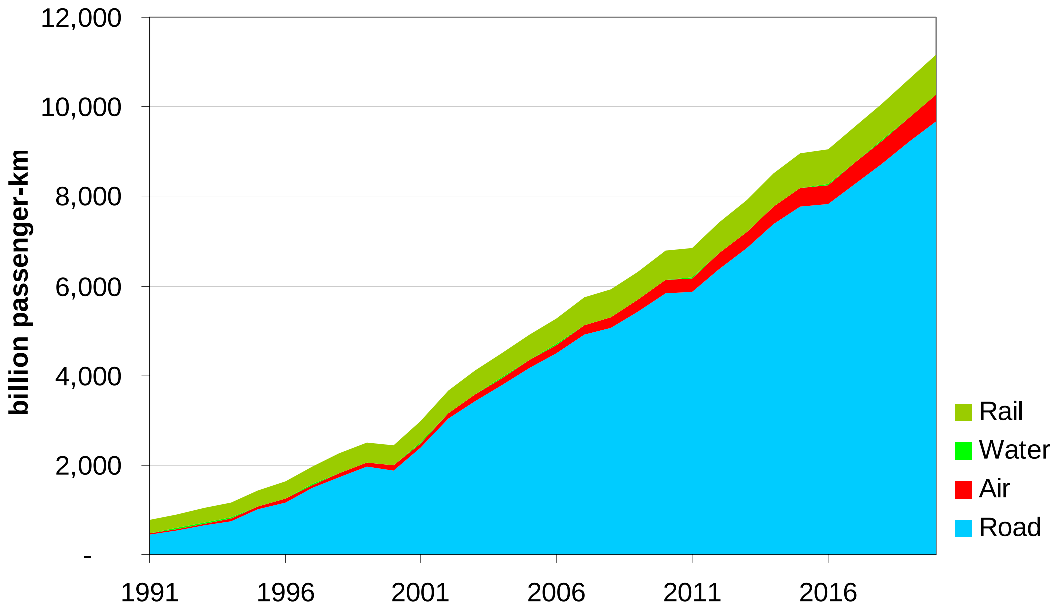


Figure 42 Passenger-km by Mode Projection

5.1.9 Ton-km by Mode Change

While passenger travel patterns are more closely related to personal wealth and lifestyle changes, freight transport activities are closely connected to overall economic activity. Based on our bottom-up analysis, the freight mobility will increase from 2952 tonne-km to 8499 tonne-km, which is most attributable to the increase in truck use (Figure 43). The shift of freight ton-km from rail to trucks will continue as it was from 1991 to 2000. Truck activity will enjoy an increase of share from 73& to 79%.

As observed in passenger transport, the share of rail freight will continue to decline from 45% to 37% from 2000 to 2020. Due to the increase of truck activity, the share of water will also shrink, while the share of air transport will remain the same. The increase in the role of trucks reflects freight toward products for which trucks have inherent advantages over competing modes, and the trend observed in China is consistent with the experience in other countries (Lee and Merer,1992).

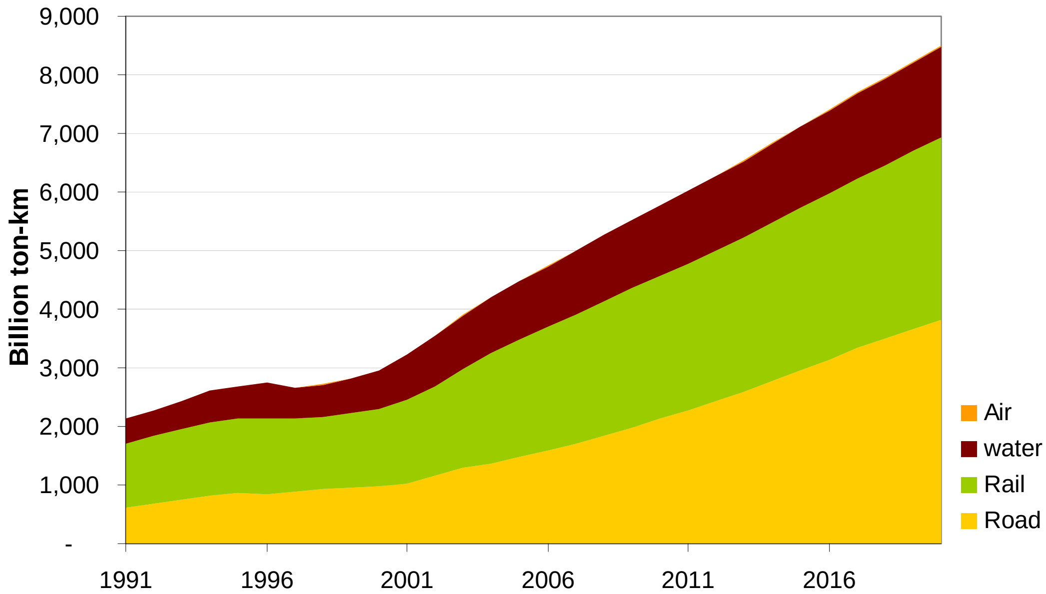


Figure 43 Tonne-km by Mode Projection

5.1.10 Car Ownership/Stock Change

The passenger vehicle stock in China is growing fastest in cars (Figure 44The vehicle fleet is forecast to grow to a total of 96 million vehicles in 2020, of which 72 million are cars (RNECSPC, 2005). Cars will increase at an AGR of 15%, followed by the buses at 12%. Car ownership will increase from 0.47% to 5.55 % cars (including government cars) per capita.

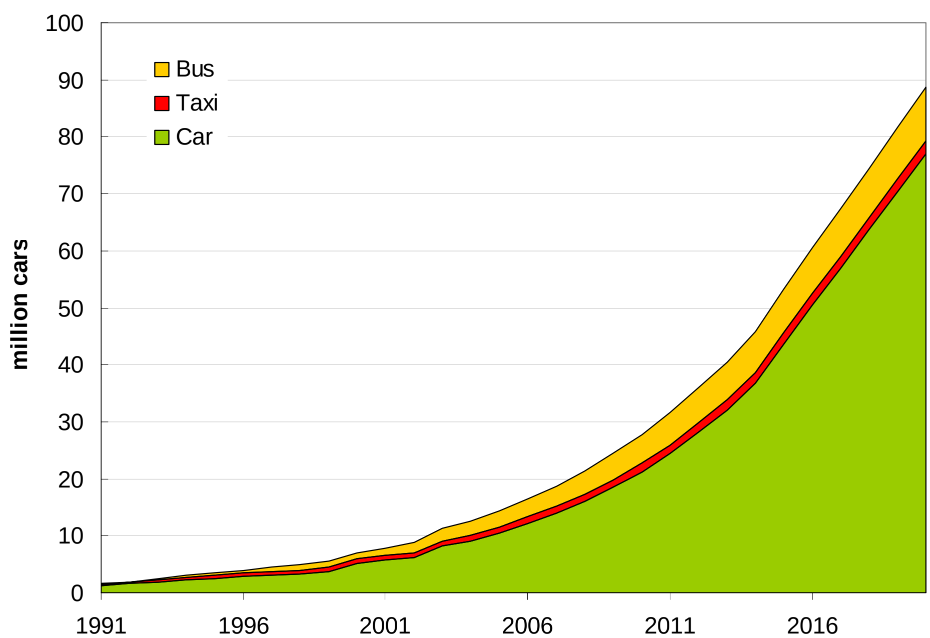


Figure 44 Vehicle Stock Projection

5.2 Energy Intensities

5.2.1 Residential End Use Intensities

For all end uses, appropriate devices and fuels were assigned, with saturation (rates of penetration) and energy efficiencies based on statistical and survey data pertaining to the base year (2000) (NBS,1985-2005; Zhou,2003, Brockett,2003) and future values based on analysis of government plans, trends, and comparisons to other countries. Table 15 shows the values for major driver variables that were used to obtain an outcome to 2020.

Table 15 Residential Energy Intensity by End-use Assumptions

		Urban enduse intensity		Rural enduse intensity		Japanese 2004 most efficient technology	note
		2000	2020	2000	2020		
Space Heating							
North	kWh/m^2-year	79	83.2	5.85	30.6		
Transition	kWh/m^2-year	29.6	28.8	5	9.6		
Cooking	MJ/household-year	901.2	1421	997	1349		
water heating	MJ/household-year	3605	5685	3988	5396		
Other use	kWh/year	100	420	50	150		
lighting	kWh/m^2-year	3	4.5	1.5	2.2		
Refrigerator UEC	kWh/year	461.2	421.9	458.9	422.3	380	for 250L-300L
Clothes washer							
vertical	kWh/year	35.88	32.9	23.9	28.1		
horizontal	kWh/year	92.4	60.9	61.36	51.5	21.9 to 40.2	for 4.2 kg
TV							
black& white	kWh/year	38	63.8	38	63.8		
color	kWh/year	125	243	125	243	79	for 29 inch
Air Conditioner UEC	kWh/year	387.6	245.6	375	248.9	47 kWh/month for cooling, 116 kWh/month for heating	for capacity of 2.5 kW

Because of their large share in household energy use, refrigerators and air conditioners were modeled in some detail. They were broken out into efficiency classes (and also, in the case of refrigerators, size classes) and simple stock turnover modeling was implemented (details are shown in Appendix). The case of refrigerators in urban households provides an example of how the efficiency changes overtime.

Current data for actual refrigerators on the Chinese market and information on possible future efficiency standards (China National Institute of Standardization, 2003) are used to determine efficiency levels for these three efficiency classes in each of three typical refrigerator sizes (170 liters, 220 liters, and 270 liters). Average intensity levels for the three efficiency classes, which are assumed to decline over the 2000 to 2030 period are shown in Figure 45. Figure 46 shows that, over the period of the scenario, the average size of new refrigerator is assume to rise. The rise of the size of refrigerators therefore offsets the efficiency improvements in each size category, that the average unit energy consumption of refrigerators shown in Table 15 would have more significant reduction otherwise.

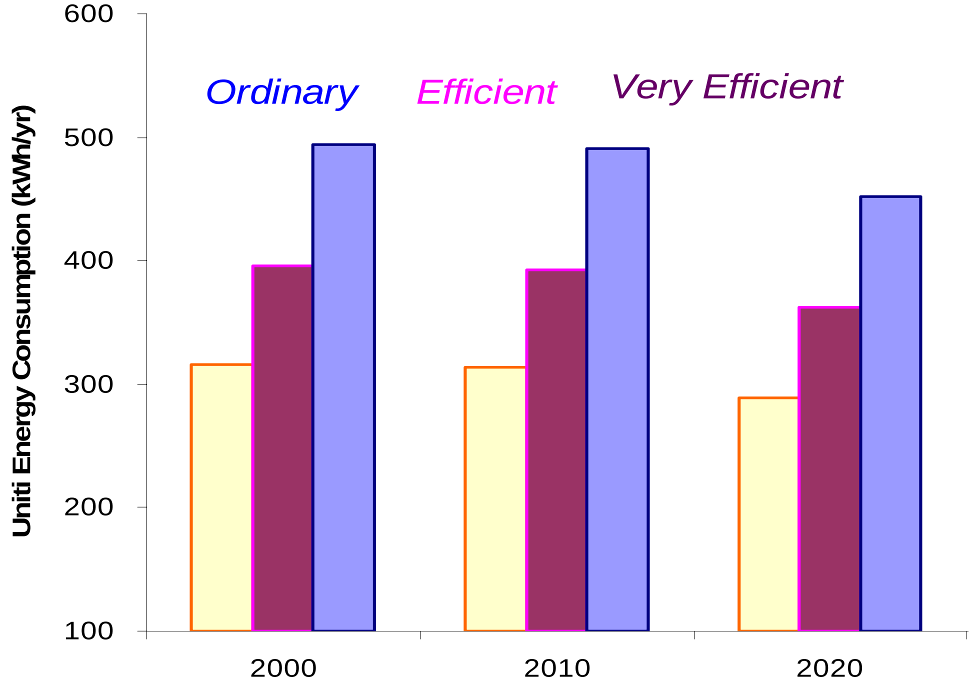


Figure 45 Refrigerator UECs by Efficiency Class

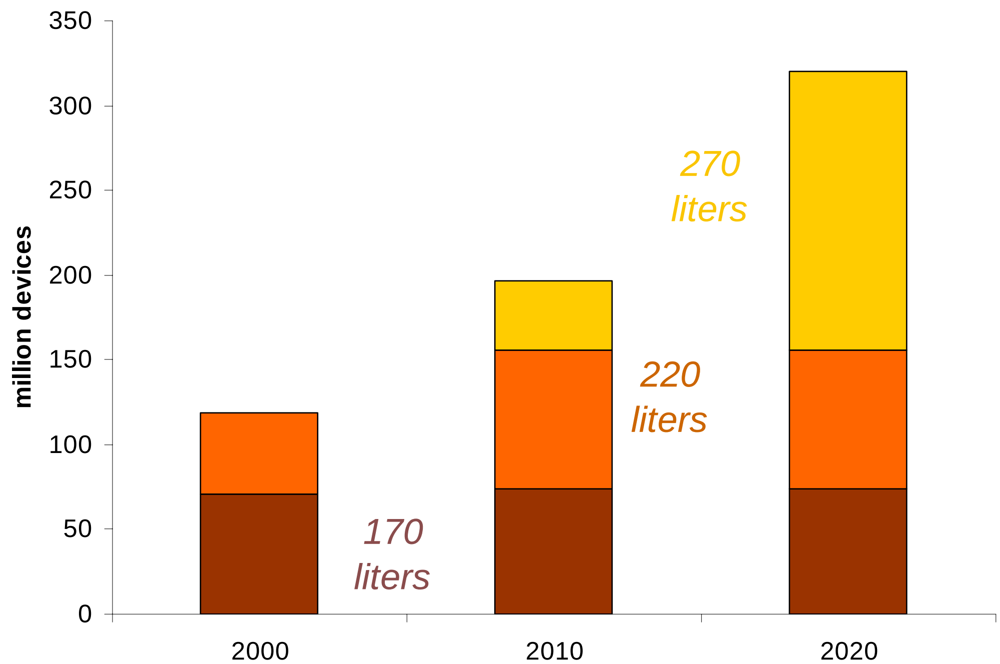


Figure 46 Refrigerator Stock by Size

5.2.2 Commercial End Use Intensities

Intensity will increase to deliver higher levels of comfort (Figure 47). Space cooling and lighting intensity in Chinese buildings is still low compared to other countries. We assume that it will grow rapidly, for example with brighter lighting of retail space or thermostats set at lower temperatures in the summer. The use of office equipment will also grow significantly, resulting in higher energy use per floor area in office buildings. Space heating stands out as the exception, since building shell improvements will allow consumers to reach higher levels of comfort with the same energy consumption. Currently, heat loss through exterior walls is about 3-5 times as high in Chinese buildings as in similar buildings in Canada or Japan. Loss through windows is over twice as high. Additional major losses are caused by imbalances and inability to control heat use in centralized heating systems, forcing consumers to commonly open windows as the only means to regulate overheating. We project significant improvements on both these fronts.

As a result of both higher end-use penetration and intensity, overall energy intensity will increase in the commercial sector. Chen (2006) indicated that the average energy intensity in Shanghai increased by 31% from 148 kWh/m^2-year in 1998 to 194 kWh/m^2-year in 2005. Our modeling results shows the average Chinese energy intensity increasing from 91 kWh/m^2-year to 104.7 kWh/m^2-year in 2020. By comparison, it increased by 12% over the 1985-2004 period in the U.S. (EERE, 2006).

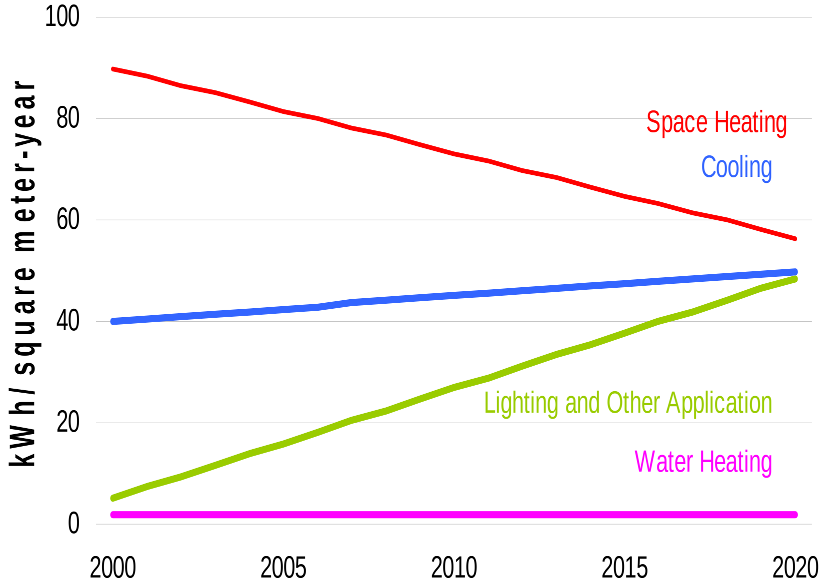


Figure 47 Commercial Energy Intensity Change by End-use

5.2.3 Space Cooling and Heating Technology Efficiency

China's government plan calls for efficiency improvement through a tightening of standards, incentives and subsidies as well as moderate measures to accelerate the adoption of higher-efficiency technologies (RNECSPC, 2005). We model energy efficiency as the combination of the efficiency and market shares of different types of technologies. Our analysis reveals a 35 percent demand-abatement potential compared with a business-as-usual scenario, mainly driven by sizable opportunities for space- and water-heating end-uses. Space heating shows a 90 percent efficiency-improvement potential, which, in turn, produces a 47 percent demand-abatement potential. This high figure is based on a double "catch-up" assumption—i.e. that both the efficiency and market shares of the different space-heating technologies used in the Chinese commercial sector will converge to their current level in Japan by 2020. As an illustration, the average efficiency of heat pumps will double and their market share rise from less than 1 percent to more than 10 percent. In parallel, the use of conventional coal boiler will decrease significantly. For lighting, state-of-the art technology includes electronic ballasts and compact fluorescent lamps (CFLs). Figure 48 shows an example of space heating technologies change respectively in office building.

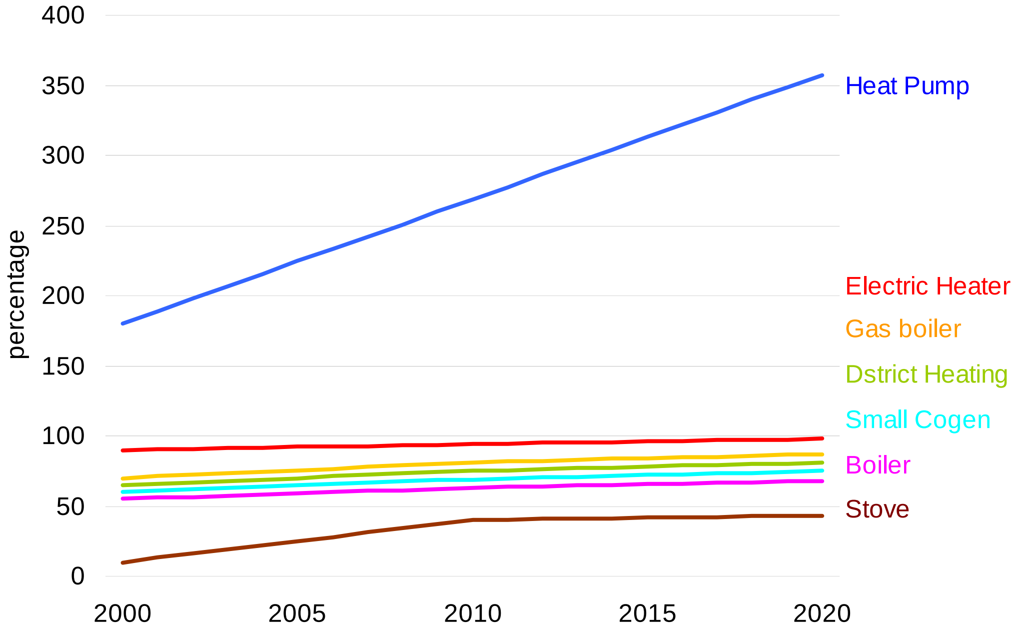


Figure 48 Example of Efficiency of Space Heating Technologies in Office Building

5.2.4   Industry Sub-sector Intensities

In aggregate terms, studies have shown that technical efficiency improvement of 1 to 2% per year is possible in the industrial sector and has occurred in the past (Ross and Steinmeyer, 1990). Energy requirements can be cut by new process development. In addition, the amount of raw materials demand by a society tends to decline as countries reach certain stages of industrial development which leads to a decrease in industrial energy use. The accounting of trends in structural shift, material intensity and technical energy efficiency and their interactions can be extremely difficult.

Changes in energy intensities can also be disaggregated into structural changes and efficiency improvements at the sub-sector level. In the iron and steel industry, energy intensity is influenced by the raw materials used (i.e. iron ore, scrap) and the products produced (e.g. slabs, or thin rolled sheets). A recent study on the iron and steel industry used physical indicators for production, distinguished six products to describe structure, and decomposed trends in seven countries which together produced almost half of the world's steel (Worrell et al., 1997b). China's government plan calls for the industrial sector to become more efficient. Table 16 shows key indicators of aggregate energy intensity in seven sub-sectors as stated in China's plan (RNESPEC, 2005)

Table 16 Energy intensity change in major industry sectors (GJ/ton)

	2000	2005	2010	2020	00-05	05-10	10-20
Glass	14.7	13.5	11.7	10.6	-1.7%	-2.8%	-1.0%
Ethylene	35.5	29.3	27.3	25.2	-3.7%	-1.4%	-0.8%
Ammonia							
coal feed stock	34.3	32.2	30.8	27.8	-1.2%	-1.0%	-1.0%
NG feed stock (kWh)	1300	1229	1168	1055	-1.1%	-1.0%	-1.0%

fuel oil feedstock	3.8	3.5	3.5	3.2	-1.3%	-1.0%	-1.0%
Paper	25.2	24.6	23.2	20.8	-0.5%	-1.1%	-1.1%
Cement							
Rotary	5.6	5.0	4.7	3.8	-1.3%	-1.4%	-2.1%
Shaft	4.7	4.4	4.2	4.1	-0.7%	-0.7%	-0.7%
Aluminum	280.2	250.6	246.2	240.3	-2.2%	-0.4%	-0.2%
Iron and Steel*	22.9	20.8	19.6	17.9	-2.0%	-1.0%	-0.9%

*Comparable energy consumption
Reference: RNECSPC (2005) and Zhou (2003)

5.3 Future Energy Outlook

5.3.1 Primary Energy Use by Sector and by Fuel

Under this scenario, China's total energy consumption by 2020 will exceed its original target by 26.12 EJ, reaching nearly 118.72 EJ (Figure 49). Industry will remain the primary energy consumption, with its share dropping from 63% in 2005 to 60% in 2020, offset mainly by rapid growth averaging over 5.5% a year expected in the commercial and transport sectors.

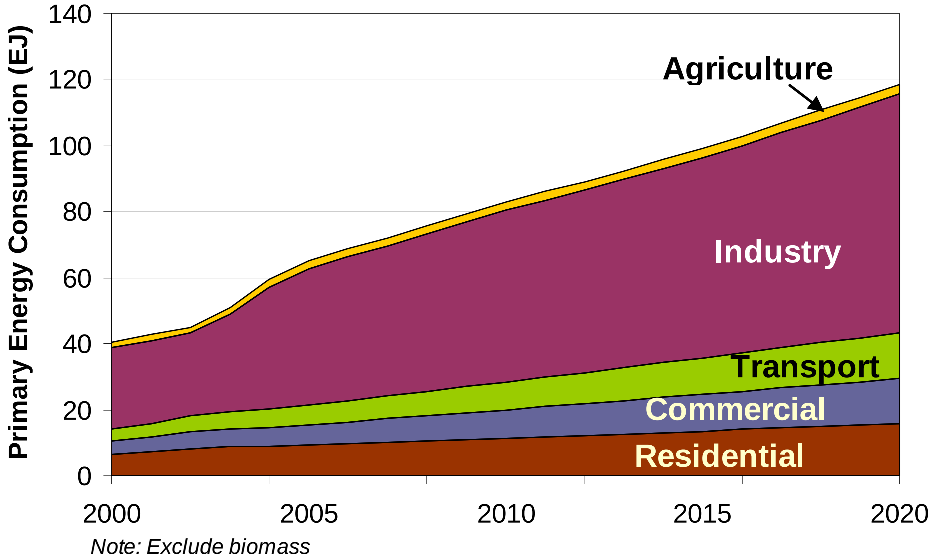


Figure 49 Primary energy consumption by sector

In terms of fuels, coal will remain dominant throughout this period, even with the aggressive plans for development of alternatives and for increasing the share of natural gas and nuclear power (Figure 50). From 70% in 2000, the share of coal will drop to about 60%, while oil—shown below split between domestically produced products and net product imports—will increase from 21% to 24%, and natural gas from 3% to 8%. Biomass, which is not include in the figure, is the backbone energy source in the rural economy, will decline slightly in volume terms, but its share will drop. Nuclear power, even with success in achieving 30 GW of installed capacity by 2020, will provide less than 1% of China's energy.
.

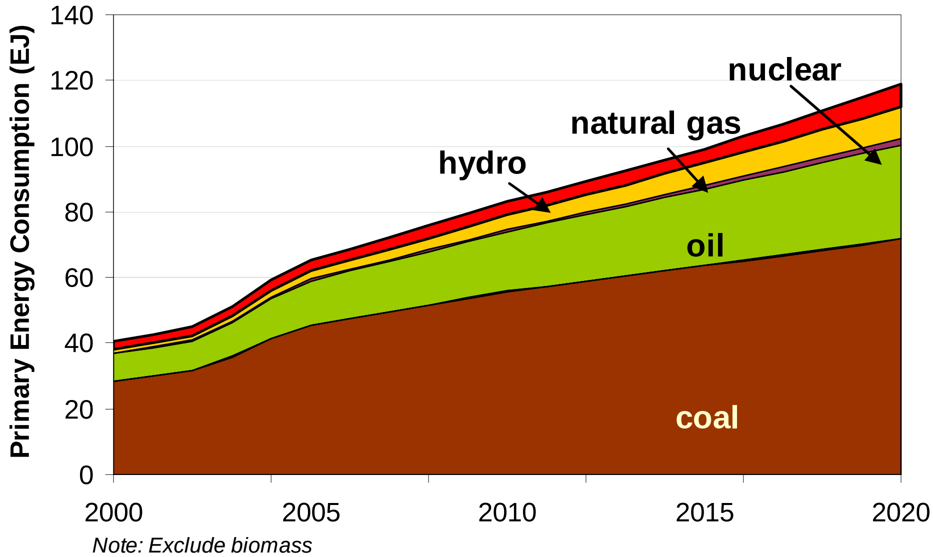


Figure 50 Primary Energy Projection by Fuel

5.3.2 Residential Energy Use by Fuel and End Use

Growth in residential and commercial energy consumption is driven both by an increase in total floor space devoted to these uses and by the increase in appliance, lighting, and heating and cooling usage in these areas (Figure 51, Figure 52, and Figure 53). As urbanization increases, growing from the current 40% to 56% in 2020, and household wealth continues to rise, demand in households for refrigerators, air conditioners, lighting products, clothes washers, consumer electronics, space heating, water heating and other functions will increase substantially. For example, the average efficiency of an "efficient" split-type room air conditioner in urban households is expected to improve by nearly 40% by 2020 over the 2004 level, but owing to continued high rates of sales, total electricity consumption by "efficient" room air conditioners is expected to more than triple, from 12 TWh in 2004 to 38 TWh in 2020.

By 2012, the total energy consumption of the 650 million urban residents will surpass that of the 728 million rural residents, even considering the 5.8 EJ consumed in rural households in the form of biomass. In terms of just commercial energy, urban household consumption will be three times that of rural areas. This high continued reliance on biomass for rural energy consumption shows the potential challenge to the coal, oil, gas and electricity sectors of fully displacing biomass usage in rural households.

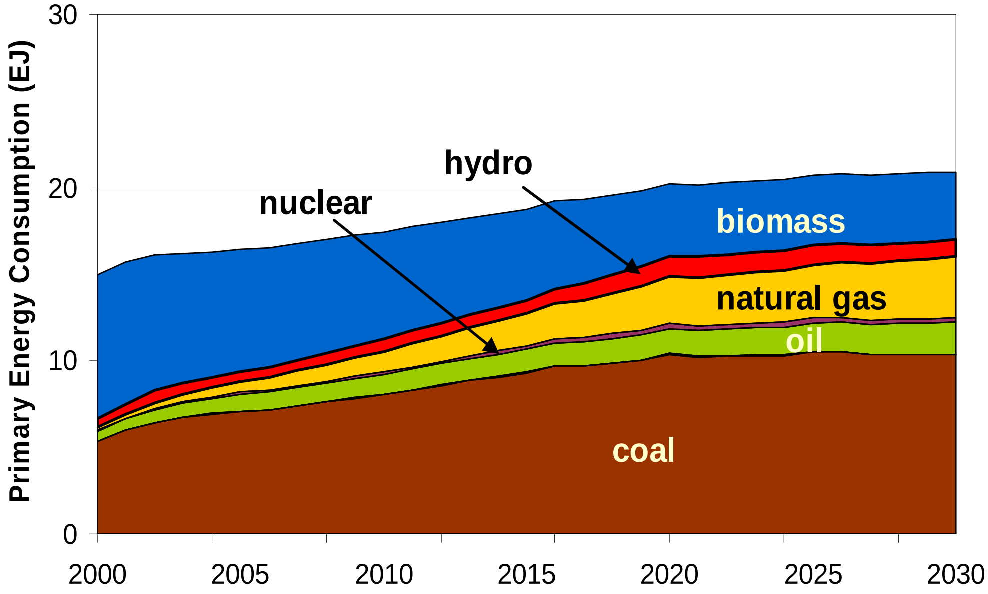


Figure 51 Residential Primary Energy Consumption by Fuel (with biomass)

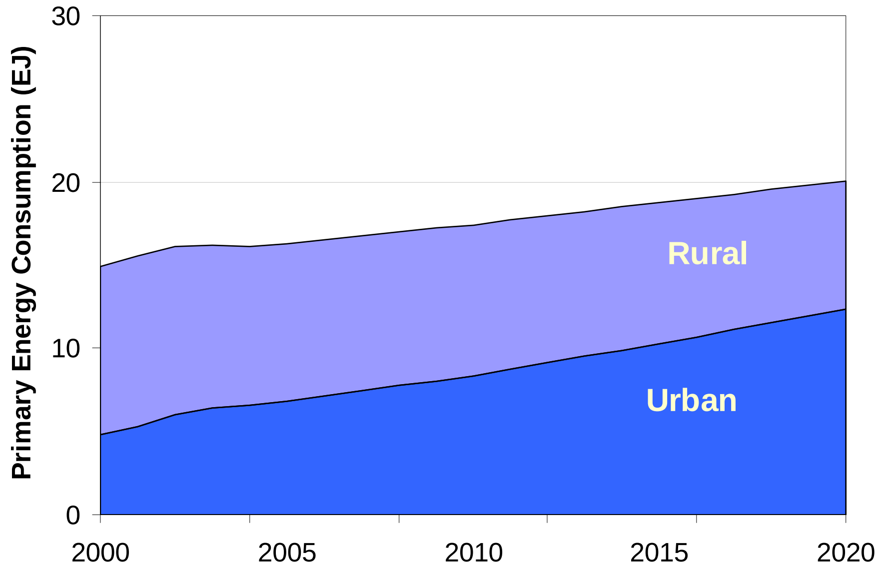


Figure 52 Residential Primary Energy Consumption in Urban and Rural (with biomass)

As living standards rise, energy efficiency improvements in the building sector are likely to be offset by the growing demand for higher levels of energy services: more space heating and cooling, improved lighting, more hot water, and larger appliances. These responses to higher living standards make it difficult to reduce energy intensity in building sector. In 2020, residential building energy consumption will reach 15.86 MJ from 6.6 MJ in 2000, with a 4.5% growth rate per year.

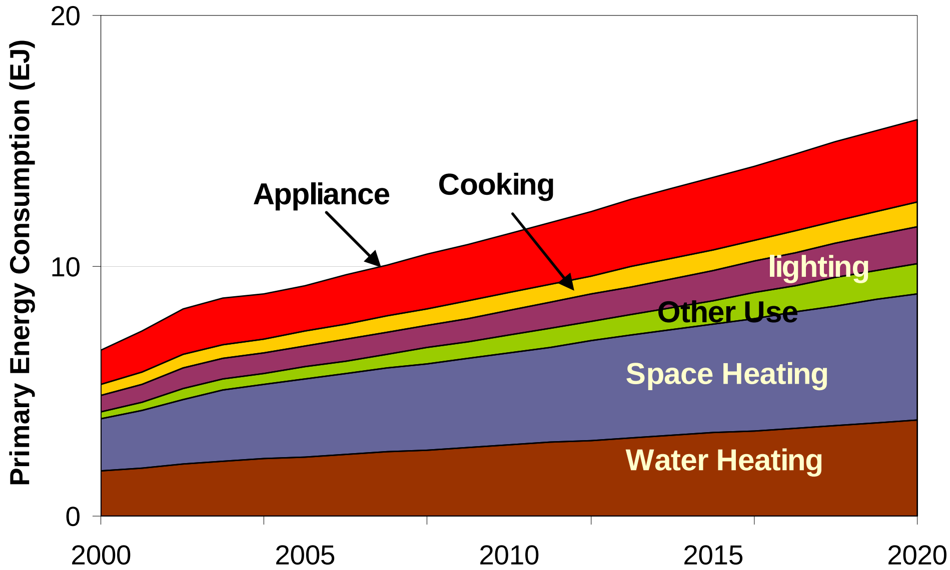


Figure 53 Residential Primary Energy Consumption by End-use (without biomass)

5.3.3 Commercial Energy Use by Fuel and End Use

Coal is the major primary energy source in the commercial sector and will continue to grow at a rate of 5.3% per year. However its share will decrease from 88% to only 69% between 2000 and 2020 (Figure 54). At the end-use level, Coal directly used on site (final energy) will phase down from 52% in 2000 to only 12% in 2020. Instead, electricity and gas will increase their share in both absolute and relative term significantly. Electricity use will increase from 15% to 47% with AGR of 12%, while gas will grow even faster from 2% to 19% at 18% AGR. Both district heat and oil will decrease its share slightly. The changes in the fuel mix reflect shifts toward more electricity-intensive end uses such as air-conditioning and other information technology equipment, and cleaner technology such as gas boilers.

Figure 55 shows commercial energy use by end use. Lighting and other electric applications are clearly the most important energy end use in commercial buildings. It accounts for 36% of the commercial energy use in 2000, and will continue to grow to 46%, at an annual growth rate of 11.6%. Space heating is the second largest end use, which accounts for 32% of the commercial energy use, and its share will decrease to 23% due to the intensity reduction and technology efficiency improvement. Water heating share will decline from 22% to 11%, while the energy used for cooling will increase significantly at 8.2% per year.

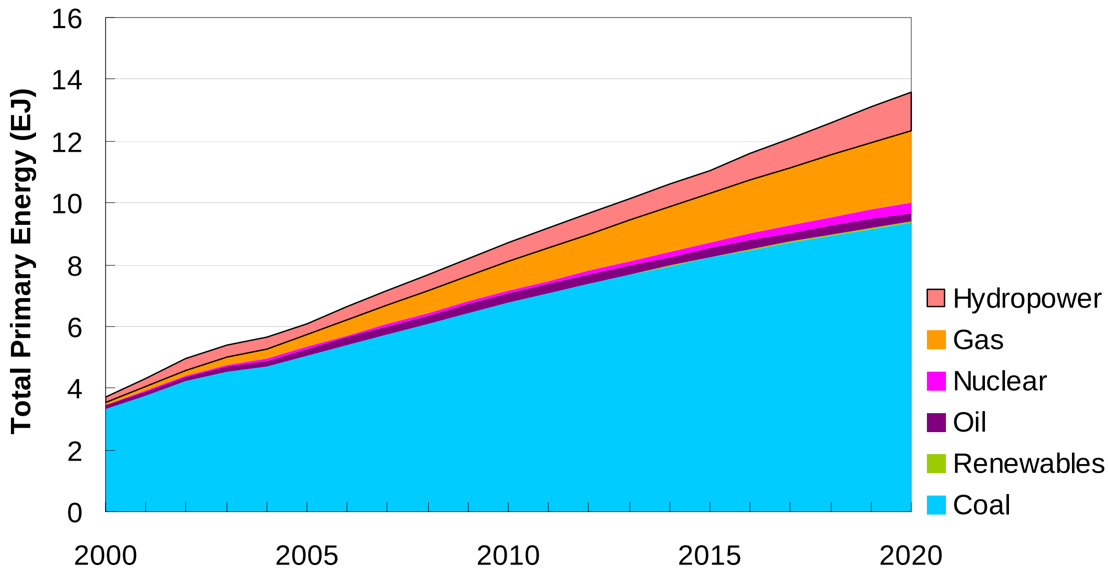


Figure 54 Commercial Primary Energy Consumption by Fuel

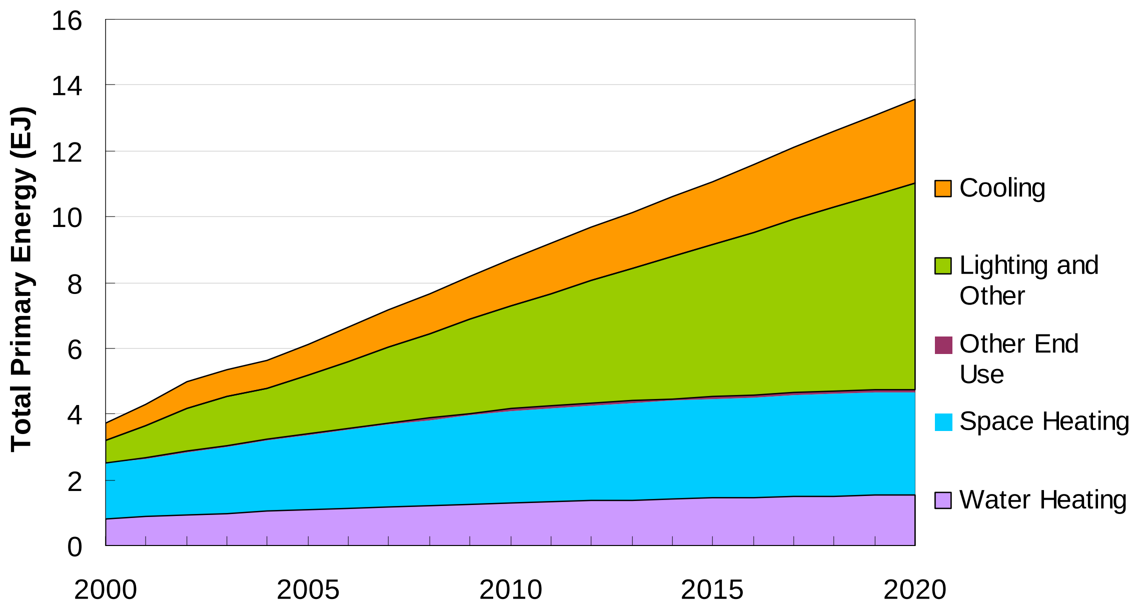


Figure 55 Commercial Primary Energy Consumption by End-use

5.3.4 Industry Energy Use by Fuel and Sub-sector

Within industry, the energy consumption of the seven sectors singled out in China's long-term development plan for substantial energy efficiency improvements will gradually decline relative to other sectors, though still account for 40% of total energy consumption in 2020, down from 53% in 2005 (Figure 56 and Figure 57). In the case of iron & steel and cement in particular, China's expected transition from rapid industrialization and infrastructure development to more intensive growth and expansion in the services sector after 2010 underlies the slowdown and eventual decline in total iron and steel output and moderation in the growth of the cement industry. Among "Other

Industry", steady increases in energy consumption growth are expected from the refining sector, the coal mining and extraction sector, and the oil and gas exploration and production sector. China's refining sector, already challenged by the requirements to produce cleaner fuels in the face of a rising proportion of high-sulfur crude oil in the processing mix, will need to add substantial numbers of energy-intensive secondary processing units such as hydrotreaters at existing refineries, in additional to the planed new processing capacity by 2020. Similarly, both the coal and oil and gas industries face higher energy consumption driven both by an expansion in the scale of activity and in rising unit energy costs of extraction as the resource base is drawn down.

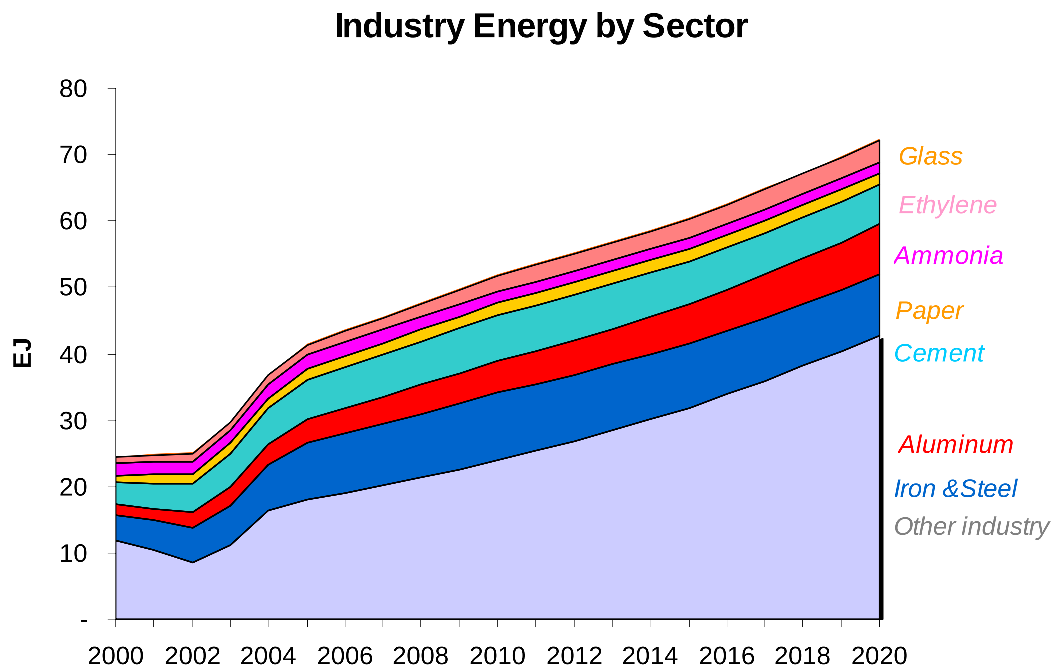


Figure 56 Industrial Primary Energy Consumption by Sub-sector

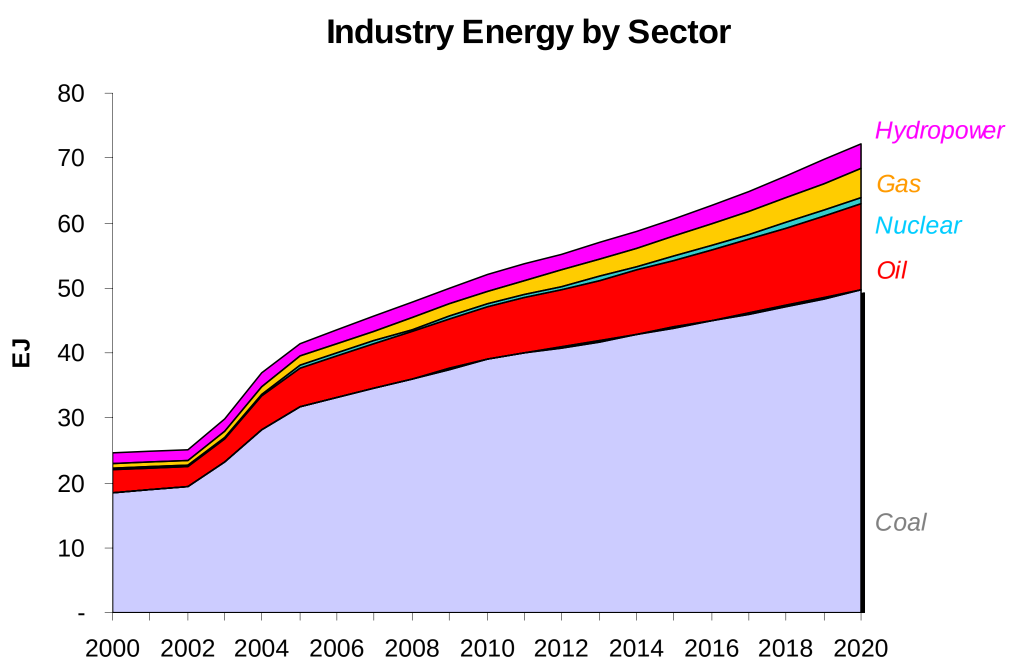


Figure 57 Industrial Primary Energy Consumption by Fuel

5.3.5 Transport Energy Use by Mode

Transport oil energy use will rise significantly by 2020, driven both by continued increases in freight transport and by expansion of passenger road travel as the personal car fleet expands (Figure 58). The annual growth rate is 7%. Transport energy end use is currently dominated by freight transport, comprising 57% of the total in 2005, but its share will decrease to 52.7% in 2000, while the share of passenger transport increases. Road dominates passenger energy use, accounting for 34% of the total transportation energy use. Cars and taxis, which are considerably more energy-intensive than public transport, together are responsible for 10% of energy use in transport sector in 2000, will increase their share to 25% by 2020 (Figure B- 17).

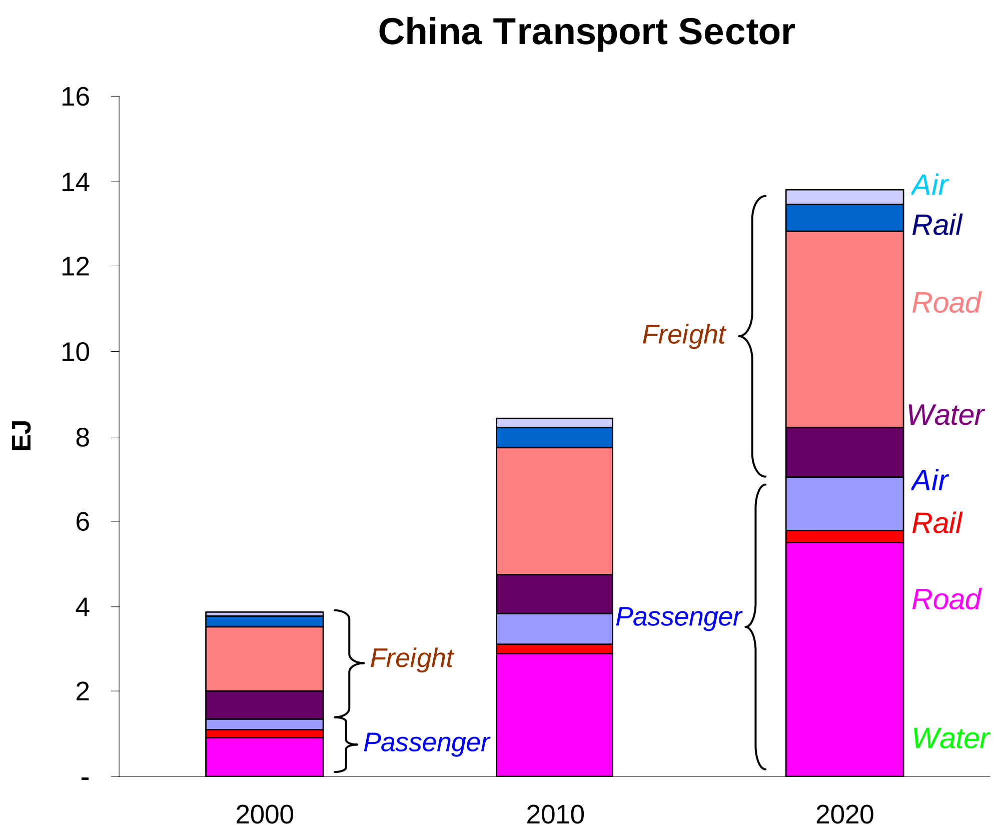


Figure 58 Transport Energy Consumption by Mode

The predominance of road fuel use in the transportation mix masks the importance of rail and water in the transport of freight. In terms of transport turnover, rail and coastal and inland water routes account for nearly 75% of all freight turnover (excluding ocean-going freight in international trade), while roads carry only 27% (Figure 59). The dramatic increase in the volume of coal carried by the rail system has led to the increasing diversion of other freight to trucks for long-distance transport. This mode diversion alone increases unit energy costs by 8 times compared to the more efficiency rail and water modes. In the absence of a dramatic increase in rail length and carrying capacity, this trend is expected to continue.

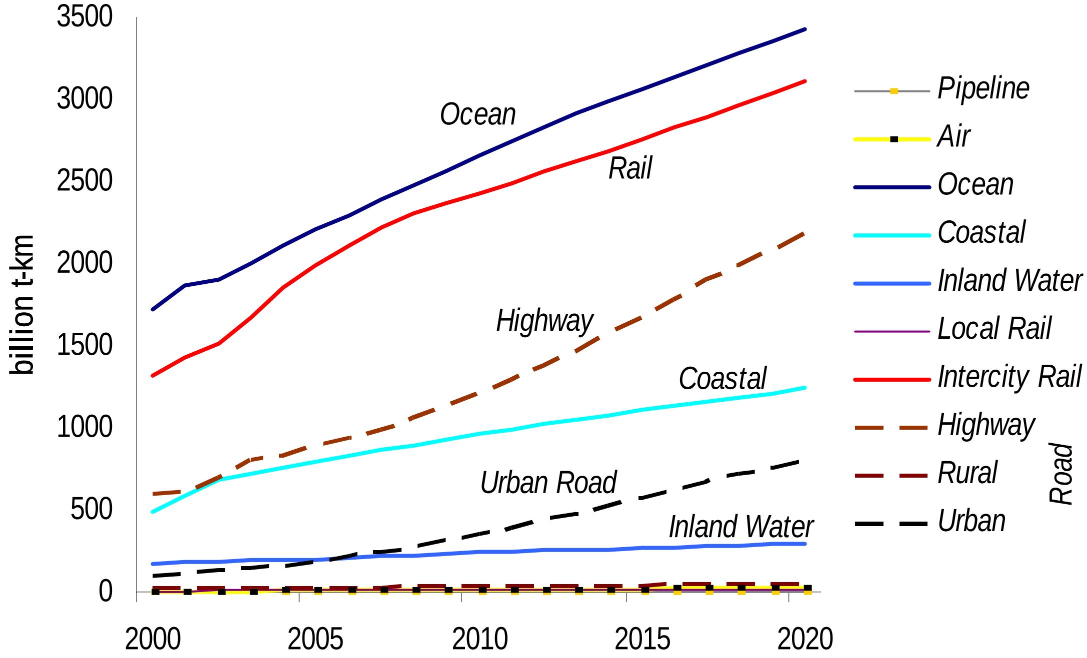


Figure 59 Freight Transport by Mode

In terms of fuels for transportation, petroleum will retain its dominance throughout the period, declining from 97% to 94% of the total by 2020 (Figure 60). Diesel consumption (used in rail, water, and trucks) is likely to remain higher than gasoline consumption (used in cars and light trucks), both accounting for 76% of total transportation fuel consumption by 2020.

Table 17 Transportation Fuel Consumption

(million boe/d)

	2000	2005	2010	2015	2020
Petroleum					
Gasoline	0.57	0.92	1.30	1.80	2.06
Jet Kerosene	0.15	0.27	0.42	0.56	0.74
Diesel	0.70	1.12	1.53	1.99	2.53
Residual Fuel Oil	0.23	0.24	0.29	0.34	0.37
Natural Gas	0.00	0.01	0.05	0.11	0.21
Electricity	0.03	0.05	0.08	0.10	0.13
Total Transportation Fuel Consumption	1.69	2.62	3.67	4.91	6.03
Petroleum as % Total	98%	97%	97%	96%	94%

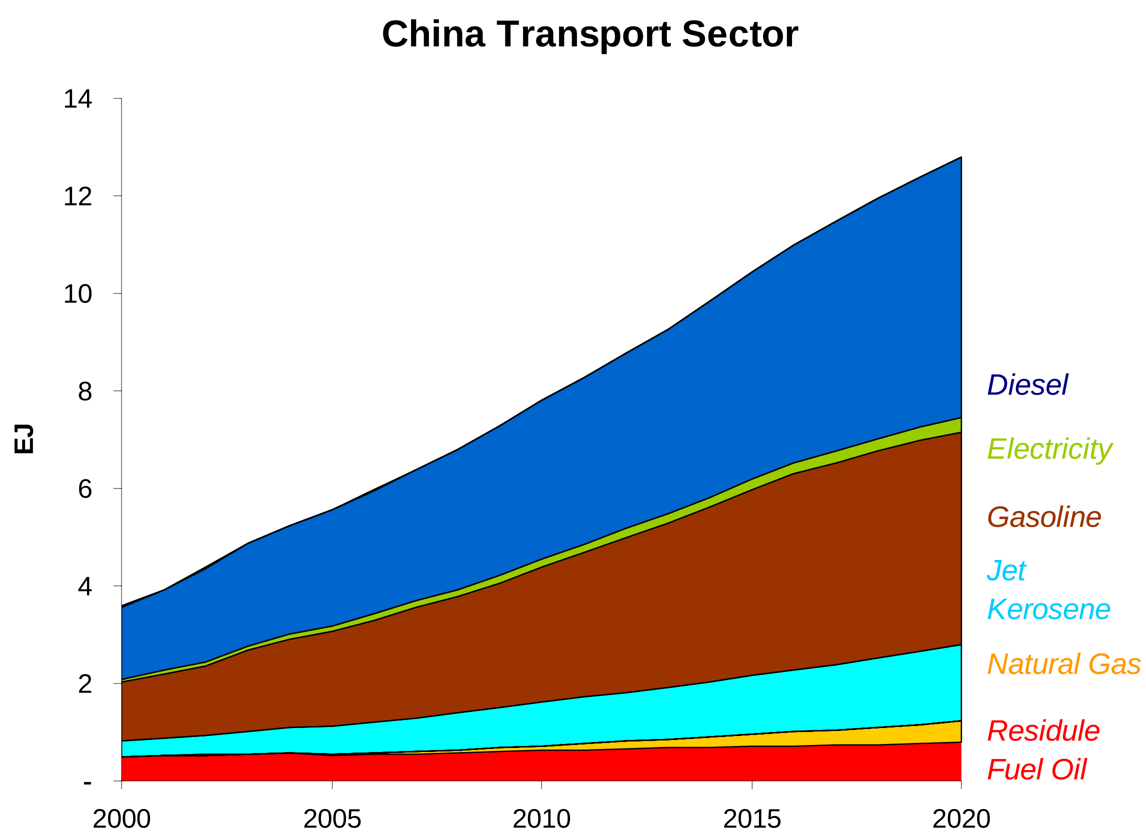


Figure 60 Transport Energy Consumption by Final Fuel

6. Conclusion

While China's 11th Five Year Plan called for a reduction of energy intensity, whether and how the energy consumption trend could be changed in a short time has been hotly debated. This report has adopted the approach of reviewing the sectoral energy consumption trends in China in detail, and making a reasonable forecast of China's future energy outlook. In then uses a detailed end-use energy model to evaluate the impacts of current efficiency policies towards meeting the government's ambitious targets towards reduction of overall energy intensity.

Sections 1 through 3 provide a methodological framework for analysis of sector energy consumption trends in China during the last ten years and makes a detailed assessment of the sector and fuel breakdown in 2000. In order to best assess the contribution from each sector, an adjustment was made to the sector definitions used in China's official energy statistics. The authors have applied judgments based on experience of working on Chinese efficiency standards and energy related programs to present a realistic interpretation of the current energy data. The bottom-up approach allows detailed consideration of end use intensity and equipment efficiency, etc. As a result, we conclude that building energy consumption in China's current statistics is underestimated by about 44% and the fuel mix is misleading. The adjusted industrial energy use accounts for 61% instead of 69%, whereas building sector account for 25% instead of 19%.

Section 4 summarizes key energy use indices by sectors and energy use using the China End-use Energy Model developed by the China Energy Group of the Lawrence Berkeley National Laboratory (LBNL). This section presents the important drivers of energy consumption at the industry sub-sector and enduse level. In each sector, energy demand is described in terms of a activity and intensity variables. This breakdown of energy drivers into activity variables and intensities allows for a deeper understanding into the state of Chinese energy consumption, and how it got there by studying trends in activity variables over the past decade. For example, in the buildings sector, we can see that the dramatic increase in ownership of appliances in urban households has driven large increases in residential electricity demand, which remains low in rural areas. In transport, demand growth is explained by increases in freight and shift in passenger transport towards road traffic. Private car ownership remains low, however. Perhaps most significantly, investigating industry production quantities and intensities in each sub-sector permits an analysis of the causes of recent consumption increases in this sector. Industrial energy consumption grew by 50% between 2002 and 2005. These increases were driven largely by growth in output from the most energy intensive sub-sectors (iron and steel and cement), which offset the gains in efficiency which were apparent across all sub-sectors.

Finally, the development of detailed end use variables and data also allows for better informed projections of energy demand in China than have previously been performed. This projection is the subject of Section 5. In this section, we project sector energy consumption according to a set of assumptions for activity variables, intensities, and efficiencies. This includes the ownership or use of appliances and vehicles trending toward levels in industrialized countries, increases in freight from a growing economy and projected production of goods from industry. Current development plan forms the basis of the "baseline" scenario evaluation in the study. There are several main conclusions to be drawn from these projections. First, industry will continue to dominate energy demand, dropping only to 60% of total demand in 2020 from 63% in 2005. Second, the percentage of transport energy used to carry passengers (instead of freight) will double from 37% to 52% between 2000 and 2020. Much of this increase is due to private car ownership, which will increase by a factor of 15 from 5.1

million in 2000 to 77 million in 2020. Residential appliance ownership will show signs of saturation in urban households, but rural homes will continue to have low consumption levels. Commercial energy increases will be driven both by increases in floor space and by increases in penetration of major end uses such as heating and cooling. These increases will be moderated somewhat, however, by technology changes, such as increased use of heat pumps.

In China's early plan (Zhou, 2003), a *Promoting Sustainability* scenario which offers a systematic and complete interpretation of the social and economic goals proposed in the Tenth Five-Year Plan would lead to a energy consumption of 80EJ in 2020. In an *Ordinary Effort* scenario, the energy consumption is projected to reach 92EJ in 2020, whereas a *Green Growth* scenario features more aggressive pursuit of sustainable development measures would lead to approximately 68EJ. However, the actual energy use in 2005 has almost reached the 2020 target in the *Green Growth* scenario, jeopardizing China's long term goal in sustainable development. Our analysis show that this increase is caused mostly by rampant growth in industries, especially energy-intensive industries such as cement, steel, and chemicals; with some exceptions, energy efficiency improvements have continued in industry even during this period of rapid energy demand growth. Further, our model results based on the revised energy consumption and production data from 2000 to 2005 indicates that even with moderate policy implementation, the energy consumption in 2020 will likely to be 26 EJ higher than the original target set in the *Ordinary Effort* scenario, and 9EJ higher than that of the *Promoting Sustainability*.

To achieve the goal, more aggressive energy efficiency improvement, policy implementation and investment in energy efficiency throughout the economy are needed. In particular, for the industry sector, structural shift away from heavy industry will be necessary, As China has already started doing, closing inefficient plants, replacing inefficient processes with more efficient processes would contribute to the target. In addition, promoting international best practice and benchmarking will offer a great opportunity in efficiency improvement. China has implemented 1000 enterprises program that require the major energy consuming enterprises, which account for 48% of the total industry energy, and about one third of the national total energy consumption, to reduce their energy by 3EJ by 2010. The results of this program remain to be seen.

In the building sector, building codes and appliance standard need to be continuously updated in order to reflect the technology improvement. Building codes exist in China but are weak compared with other developed countries. In addition, compliance rates in China are fairly low. In southern cities, the compliance rate in new buildings could be as low as 8 to 10%. Government at all level should increase the capacity and resource for inspection and enforcement. Further, heat metering system need to be put in place to assure the success of heating reform. Currently, the loss from the central heating system is still very significant.

In the transportation sector, China should further tighten fuel economy standards beyond 2008 to offset escalating vehicles sales. Standard enforcement is also critical to ensure the new vehicle to meet the minimum level of the fuel efficiency. More effort less should be made to promoting public transportation system. In addition, integrated transportation system design should be incorporate d into urban planning or land development process, to have a more systematic and efficient transportation system, Furthermore, fiscal and tax instruments such as fuel tax, pricing and incentives to cleaner and more efficient vehicles will be important measures to steer the wheel to a more efficient transportation system,

References

Ang, BW, and K.H. Choi, 1997. "Decomposition of Aggregate Energy and Gas Emission Intensity for Industry: A Refined Divisia Index Method." *The Energy Journal* 18(3):59-73

Battles, S., and Burns, E., 2000. Trends in Building-Related Energy and Carbon Emissions: Actual and Alternate Scenarios, *Summer Study on Energy Efficiency in Buildings*, August 21, Washington, DC: American Council for an Energy-Efficient Economy.

BP-Amoco, 2001, BP Statistical Review of World Energy 2001, www.bp.com/centres/energy/world_stat_rev, (BP-Amoco, London).

Brockett,D., Fridley, D., Lin,JM, and Lin, J 2003. A Tale of Five Cities: The China Residential Energy Consumption Survey, Human and Social Dimension of Energy Use: Understanding Markets and Demand

Chen, Y., Piao, A., and Xiao, Z.. China's Transport Prospects, 17th World Energy Congress, Houston, Texas, 1998

Chen Chen, Yiqun Pan, Zhizhong Huang and Zhenfei Lou, 2006, The Establishment and Application of Commercial Building Information Database for Shanghai, Shanghai Energy Conservation Supervision Center

China Association of Transportation & Communications, 1985-2005. *Year Book of China Transportation & Communications*, Year Book House of China Transportation & Communications.
Committee of RNECSPC, 2005. *Research on National Energy Comprehensive Strategy and Policy of China* (RENESPEC), Economic Science Press

Committee of RNECSPC, 2005. *Research on National Energy Comprehensive Strategy and Policy of China* (RENESPEC), Economic Science Press

Energy Efficiency and Renewable Energy (EERE) of Department of Energy (DOE), 2006. Indicators of Energy Intensity in the Unites States, http://intensityindicators.pnl.gov/total_commercial.stm
Energy Information Administration (EIA), 2001, *International Energy Outlook 2001*, Report No. DOE/EIA-0484, Washington D.C.: EIA/US DOE

Energy Information Administration (EIA), 2006, *The International Energy Outlook 2006 (IEO2006)*, Washington D.C.: EIA/US DOE

Energy Information Administration (EIA), 2006a, *Annual Energy Review 2006*, Washington D.C.: EIA/US DOE

Energy Research Institute (ERI), 2003. China Sustainable Development Energy and Carbon Emission Scenarios.

He, K., Huo,H., Zhang, Q., He, D., An,F., Wang,M., and Walsh, M., 2005. "Oil consumption and CO_2 emissions in China's road transport: current status, future trends, and policy implications." *Energy Policy,* Volume 33, Issue 12, August, pp. 1499-1507

IEA, 1997. *Indicators of Energy Use and Efficiency: Understanding the Link between Energy and Human Activity*, Paris, IEA/OECD.

Institute of Energy Economics, Japan (IEEJ), 2003. *Handbook of Energy & Economic Statistics in Japan*, he Energy Data and Modeling Center, The Institute of Energy Economics, Tokyo, Japan

International Energy Agency (IEA), 2001, Energy Statistics of Non-OECD Countries 1998-1999 (IEA, Paris).

International Energy Agency (IEA),2004. 30 Years of Energy Use in IEA Countries, Paris: IEA/OECD.

International Energy Agency (IEA),2003.2004. Key World Energy Statistic, Paris: IEA/OECD.

Institute of Energy Economics, Japan (IEEJ), 2003. *Handbook of Energy & Economic Statistics in Japan*, the Energy Conservation Center, Japan

Lin, J, 2003. A Light Diet for a Giant Appetite: An Assessment of China's Fluorescent Lamp Standard, *Energy,* No.30, pp8-35

Nadel, S.M., Fridley, D., Sinton, J., Zhirong, Y., Hong, L., 1997. Energy Efficiency Opportunities in the Chinese Building Sector. Washington, DC: American Council for an Energy-Efficient Economy.
National Bureau of Statistics (NBS), 1985-2005. *China Statistical Yearbooks.* Beijing: NBS.

National Bureau of Statistics of China (NBS), 1981-2005. China Statistical Yearbooks. Beijing: Info Press. http://www.stats.gov.cn/english/statisticaldata/yearlydata/

National Development and Reform Commission (NDRC), 2005. Medium- and Long-term Conservation Plan, China Environmental Science Press, Beijing.

Price, L., Stephane de la Rue du Can, Sinton, J., Worrell, E., Zhou, N., Sathaye, J., and Mark Levine, 2006. *Sectoral Trends in Global Energy Use and Greenhouse Gas Emissions*, LBNL-56144

Sathaye, J., Ketoff, A., Schipper, L., and Lele, S., 1989. An End-Use Approach to Development of Long-Term Energy Demand Scenarios for Developing Countries, Berkeley, CA, LBNL (LBL-25611).

Sathaye, J., Ketoff, A., Schipper, L., and Lele, S.: 1989, An End-Use Approach to Development of Long-Term Energy Demand Scenarios for Developing Countries, Berkeley, CA, LBNL (LBL-25611).

Schipper, L., Hass, R., and Sheinbaum, C., 1996. "Recent Trends in Residential Energy Use in OECD Countries and Their Impact on Carbon Dioxide Emissions: A Comparative Analysis of the Period 1973-1992," *Journal of Mitigation and Adaptation Strategies for Global Change* 1, 167-196.

Schipper, L., Meyers, S., Howarth, R., and Steiner, R., 1992. *Energy Efficiency and Human Activity*, Cambridge University Press, Cambridge: UK

Sinton, J.E., Fridley, D.G., Levine, M.D., Yang, F., Zhenping, J., Xing, Z., Kejun, J., and Xiaofeng, L., Eds. 1996. China Energy Databook, Berkeley, CA: Lawrence Berkeley National Laboratory, LBL-32822. Rev.4, Version No. 4, September, 1996.

Sinton, J., 2001. "Changing Energy Intensity in Chinese Industry", Lawrence Berkeley National Laboratory, LBNL- 48919

Sinton, J., and Levine, M.,1994. "Changing Energy Intensity in Chinese Industry", *Energy Policy*, 22(3):239-258.

Sinton, J., and Fridley, D, 2003. "Comments on Recent Energy Statistics from China", Lawrence Berkeley National Laboratory, LBNL- 53856.

Sinton, J., Fridley, D., Lewis, J., Lin,J., Chen, Y., and Zhou,N., 2004. China Energy Databook, version 6. Lawrence Berkeley National Laboratory, LBNL-55349.

United Nations (UN), 2003. *World Population Prospects: The 2002 Revision*, United Nations Population Division. www.unpopulation.org.

United Nations, 2005. *World Population Prospects: The 2005 Revision*. Department of Economic and Social Affairs. Population Division.

United States Geological Survey (USGS), 2007. *Mineral Commodity Summary.* http://minerals.usgs.gov/minerals/pubs/commodity/cement/

Wang, Q, 2005. *2005 Energy Data for Fiscal and Economic Policy Sustainable Energy Development Research*, The China Sustainable Energy Program, Energy Foundation

Wang,Q, Sinton, J., and Levine, M., 1995. *China's Energy Conservation Policies and Their Implementation, 1980 to the Present, and Beyond*. LBNL, December

World Bank, 2003. World Development Indicators 2003. The Word Bank: Washington, DC.

World Energy Council (WEC), 2001. *Survey of Energy Resources*, WEC. Available online at http://www.worldenergy.org/wec-geis/publications/reports/ser/overview.asp

World Energy Council (WEC), 2004. *Energy End-Use Technologies for the 21st Centry*, WEC.
Zhou, D., Dai,Y., Yu, C., Guo, Y. and Zhu,Y., 2003. *China's Sustainable Energy Scenarios in 2020*, China Environmental Science Publishing Company.

Zhou, D., Dai,Y., Yu, C., Guo, Y. and Zhu,Y., 2003. China's Sustainable Energy Scenarios in 2020, China Environmental Science Publishing Company

Chen Y., Piao A., and Xiao, Z.2003. 'China's Transport Prospects'.

Appendix A. Description of Stock Turnover Analysis

In this study, LEAP (Long-range Energy Alternative Planning System) was used to build the end-use model, and the bottom-up approach allowed a detailed consideration of end-use efficiency and technology share. The model incorporates selected technologies and related data including stock, energy intensity and saturation levels, to reach the energy consumption levels envisioned. The end uses were further broken out by technologies; Refrigerator and Air conditioner were broken out into classes by level of service, associated with different levels of efficiency (Figure 61).

For a given technology branch, stock turnover modeling was implemented. In this method, energy consumption is calculated by analyzing the current and projected future stocks of energy-using devices, and the annual energy intensity of each device. LEAP then calculates the stock average energy intensity and across all vintages and hence, ultimately, the overall level of energy consumption

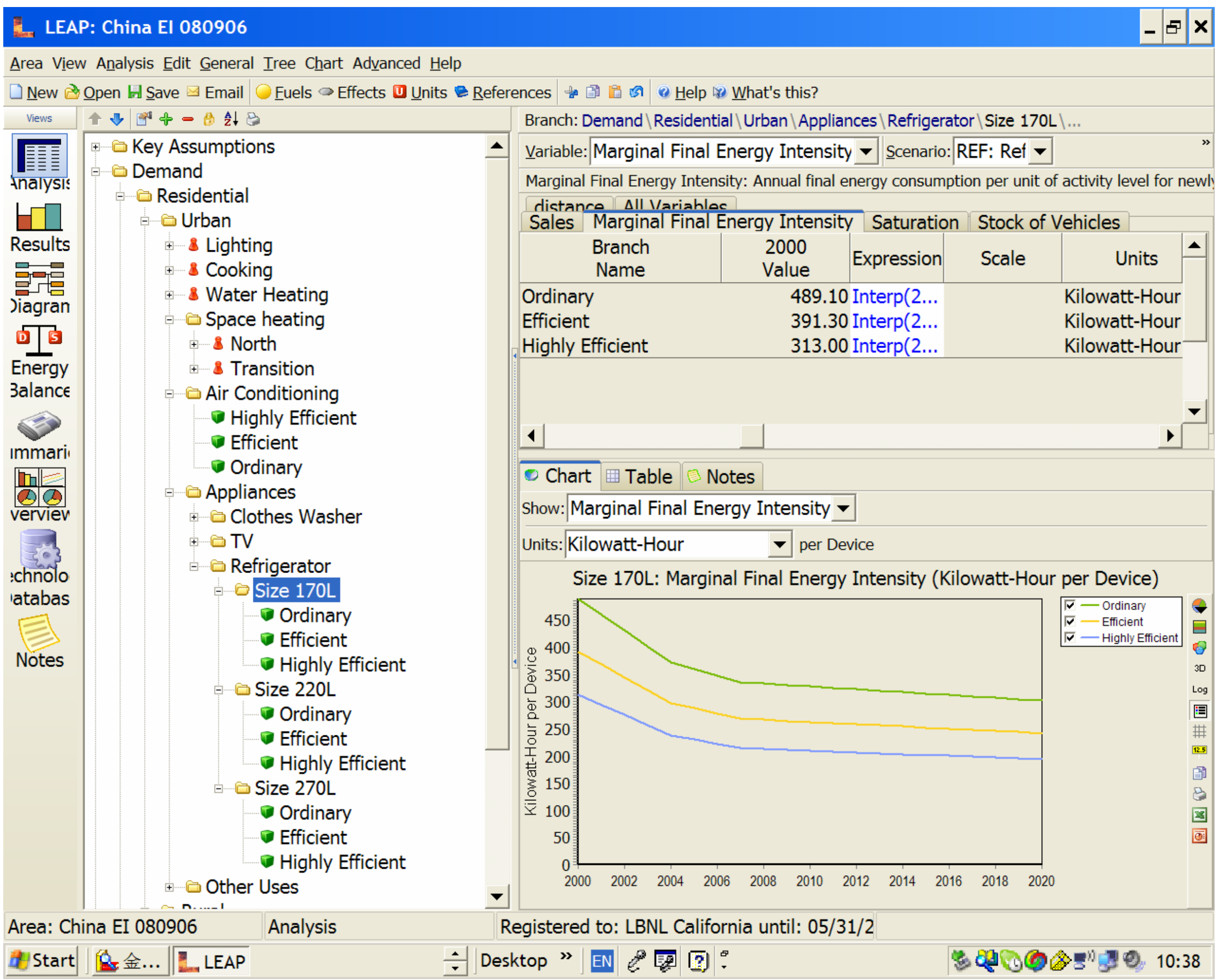


Figure 61: Structure of LEAP model

The following equations describe the calculations for the stock analysis methodology:

A- 1 Stock Turnover

$$Stock_{t,y,v} = Sales_{t,y} * Survival_{t,y-v}$$

$$Stock_{t,y} = \sum_{v=0..V} Stock_{y,v,t}$$

Where:

t is the type of technology (i.e. the technology branch)
v is the vintage (i.e. the year when the technology was added)
y is the calendar year
Sales: is the number of devices added in a particular year
Stock is the number of devices existing in a particular year:
Survival is the fraction of devices surviving after a number of years, and
V is the maximum number of vintage years

Published NBS appliance ownership, sales, and trade data are not always internally consistent. Most of the appliance sales estimates in this report were calculated according to household ownership data and implied retirement replacement. Section A-2 outlines the ownership and lifetime assumptions that serve as the basis for LBNL's stock turnover model.

A- 2 Energy Intensity

$$EnergyIntensity_{t,y,v} = EnergyIntensity_{t,y} * Degradation_{t,y-v}$$

Where:

EnergyIntensity is energy use per device for new devices purchased in year y.
Degradation is a factor representing the change in energy intensity as a technology ages. It equals 1 when y=v. In our analysis, the degradation profile is only used for Refrigerator and Air Conditioner.

A- 3 Energy Consumption

$$EnergyConsumption_{t,y,v} = Stock_{t,y} * EnergyIntensity_{t,y-v}$$

Appendix B. Tables

Urban Residential Sector

Variable: Air Conditioning: Marginal Final Energy Intensity (Kilowatt-Hour per Device)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Highly Efficient	272	238	193	174	157
Efficient	341	298	242	218	196
Ordinary	420	372	302	272	245

Variable: Air Conditioning: Saturation
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Highly Efficient	0	0.6	1.5	2.5	3.8
Efficient	9.2	11.4	14.1	17.6	22.1
Ordinary	21.6	24.3	26.3	27.7	28.5
Total	30.8	36.3	41.9	47.9	54.4

Variable: Air Conditioning: Sales (Million Devices)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Highly Efficient	0.9	1.8	2.1	2.5	2.8
Efficient	4.4	8.8	10.5	12.2	14
Ordinary	3.5	7.1	8.5	9.8	11.2
Total	8.8	17.7	21.1	24.5	27.9

Variable: TV: Saturation
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Black TV	0	0	0	0	0
Color TV	117	123	129	135	142
Total	117	123	129	135	142

Variable: TV: Final Energy Intensity (Kilowatt
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Black TV	38	44.5	50.9	57.4	63.8
Color TV	125	152	180	207	235

Variable: Clothes Washer: Final Energy Intensity (Kilowatt-Hour per Household)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Vertical	25	24	22.9	21.6	20.1
Horizontal	49.9	48	45.8	43.2	40.3

Variable: Clothes Washer: Saturation
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Vertical	63.4	61.4	59.3	57.1	54.9
Horizontal	27.1	30.7	34.3	38.1	42
Total	90.5	92.1	93.7	95.3	96.8

Variable: Urban: Useful Energy Intensity (Megajoule per Household)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Cooking	901	1,031.20	1,161.10	1,291.00	1,421.00

Variable: Cooking: Efficiency (Efficiency)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
electricity	90	90	90	90	90
natral gas	65	65.8	66.5	67.3	68
LPG	60	60	60	60	60
coal	30	31.3	32.5	33.8	35
other	45	45.8	46.5	47.3	48
Coal Gas	60	60	60	60	60

Variable: Cooking: Activity Level (% Share of Households)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
electricity	10.3	12.7	15.2	17.6	20
natral gas	14.9	21.4	27.9	34.5	41
LPG	43.4	37.5	31.7	25.9	20
coal	17.1	14.1	11.1	8	5
other	5.2	6.7	8.1	9.6	11
Coal Gas	9.1	7.6	6	4.5	3
Total	100	100	100	100	100

Variable: Urban: Final Energy Intensity (Kilowatt-Hour per Square Meter)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Lighting	3	3.3	3.7	4	4.5

Variable: Lighting: Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Incandescent	55	50.9	46.7	42.5	38.4
Fluorescent	39	40.8	42.6	44.5	46.3
CFL	6	8.3	10.6	13	15.3
Total	100	100	100	100	100

Variable: Size 270L: Sales (Million Devices)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Ordinary	0.6	3.7	10.4	15.3	19.7
Efficient	0.2	1.3	3.7	5.5	7
Highly Efficient	0	0.3	0.7	1.1	1.4
Total	0.9	5.3	14.8	21.9	28.1

Variable: Size 220L: Sales (Thousand Devices)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Ordinary	5,135.20	4,475.70	868.8	0	0
Efficient	1,834.00	1,598.50	310.3	0	0
Highly Efficient	366.8	319.7	62.1	0	0
Total	7,336.00	6,393.90	1,241.10	0	0

Variable: Size 170L: Sales (Thousand Devices)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Ordinary	641.9	107	0	0	0
Efficient	229.3	38.2	0	0	0
Highly Efficient	45.9	7.6	0	0	0
Total	917	152.8	0	0	0

Variable: Size 270L: Marginal Final Energy Intensity (Kilowatt-Hour per Device)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Ordinary	609.6	525.6	477.8	459	440
Efficient	487.7	420.5	382.3	367	352
Highly Efficient	390.1	336.4	305.8	294	282

Variable: Size 220L: Marginal Final Energy Intensity (Kilowatt-Hour per Device)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Ordinary	543.9	473.3	431.5	415	398
Efficient	435.1	378.2	344	330	317
Highly Efficient	348.1	302.9	276.2	265	254

Variable: Size 170L: Marginal Final Energy Intensity (Kilowatt-Hour per Device)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Ordinary	489.1	360.1	328	315	302
Efficient	391.3	288.1	262.4	252	242
Highly Efficient	313	230.5	209.9	202	193

Commercial Sector

Variable: Commercial: Activity Level (% Sha
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Office	33.3	32.1	31	29.8	28.6
Retail	14.1	15.8	17.6	19.3	21
Hospital	3.8	4.1	4.3	4.6	4.9
School	17	17.6	18.2	18.9	19.5
Hotel	14.1	12.7	11.3	9.8	8.4
Other	17.7	17.7	17.6	17.6	17.6
Total	100	100	100	100	100

Variable: Office: Activity Level (% Saturation of Square Meters)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Lighting and Other Application	100	100	100	100	100
Water Heating	100	100	100	100	100
Space Heating	35	40	45	50	55
Cooling	20	28.8	37.5	46.3	55

Variable: Retail: Activity Level (% Saturation of Square Meter
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	35	40	45	50	55
Cooling	31	37	43	49	55
Lighting and Other Application	100	100	100	100	100
Water Heating	100	100	100	100	100

Variable: Hospital: Activity Level (% Saturation of Square Me
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	35	40	45	50	55
Cooling	20	27.5	35	42.5	50
Lighting and Other Application	100	100	100	100	100
Water Heating	100	100	100	100	100

Variable: School: Activity Level (% Saturation of Square Meters)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	35	40	45	50	55
Cooling	7	15.3	23.5	31.8	40
Lighting and Other Application	100	100	100	100	100
Water Heating	100	100	100	100	100

Variable: Hotel: Activity Level (% Saturation of Square Meters
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	35	40	45	50	55
Cooling	31	37	43	49	55
Lighting and Other Application	100	100	100	100	100
Water Heating	100	100	100	100	100

Variable: Other: Activity Level (% Saturation of Square Meters
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	35	38.8	42.5	46.3	50
Cooling	20	28.8	37.5	46.3	55
Lighting and Other Application	100	100	100	100	100
Water Heating	100	100	100	100	100
Other End Use	100	100	100	100	100

Variable: Office: Useful Energy Intensity (Kilowatt-Hour per Square Meter)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Lighting and Other Application	5.2	16	26.8	37.7	48.5
Water Heating	1.9	1.9	1.9	2	2
Space Heating	90	81.6	73.2	64.8	56.4
Cooling	40	42.5	45	47.4	49.9

Variable: Retail: Useful Energy Intensity (Kilowatt-Hour per Sq
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	70	65.9	61.7	57.6	53.4
Cooling	86	89	92	95	98
Lighting and Other Application	22	34.6	47.2	59.8	72.4
Water Heating	18.7	19	19.2	19.5	19.8

Variable: Hospital: Useful Energy Intensity (Kilowatt-Hour per Square Meter)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	80	73.3	66.5	59.8	53.1
Cooling	50	52.4	54.9	57.3	59.8
Lighting and Other Application	8	19.4	30.9	42.3	53.7
Water Heating	65	65.9	66.9	67.8	68.8

Variable: School: Useful Energy Intensity (Kilowatt-Hour per Square Meter)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	70	64.1	58.2	52.3	46.3
Cooling	30	31	32	33	34
Lighting and Other Application	4.1	5.9	7.7	9.5	11.3
Water Heating	1.9	1.9	1.9	1.9	1.9

Variable: Hotel: Useful Energy Intensity (Kilowatt-Hour per Square Meter)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	70	75.4	80.8	86.2	91.5
Cooling	70	72.3	74.6	76.8	79.1
Lighting and Other Application	22	33.3	44.7	56	67.3
Water Heating	65	65.9	66.9	67.8	68.8

Variable: Other: Useful Energy Intensity (Kilowatt-Hour per Square Meter)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Space Heating	80	73.3	66.5	59.8	53.1
Cooling	40	42.5	45	47.4	49.9
Lighting and Other Application	5.2	16	26.8	37.7	48.5
Water Heating	1.9	1.9	1.9	2	2

Variable: Water Heating: Efficiency (Efficiency)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Boiler	55	59	63	65.5	68
Gas Boiler	70	75.5	81	84	87
Small Cogen	60	64.5	69	72	75
Electric Water Heater	90	92	94	96	98
Oil	70	75.5	81	84	87

Variable: Space Heating: Efficiency (Efficiency)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
District Heating	65	70	75	78	81
Boiler	55	59	63	65.5	68
Gas Boiler	70	75.5	81	84	87
Small Cogen	60	64.5	69	72	75
Electric Heater	90	92	94	96	98
Stove	10	25	40	41.5	43
Heat Pump	180	224	269	313	357

Variable: Cooling: Efficiency (Efficiency)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Centralized AC	180	185	191	196	200
Room AC	250	257	263	264	265
Geothermal Heat Pump	300	308	315	317	318
Centralized AC by NG	120	123	126	127	127

Industry

Variable: Industry: Activity Level (Million Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Iron and Steel	128.5	349.4	440	440	440
Aluminium	3	7.7	11.2	14.7	19.2
Cement	597	1,050.00	1,310.00	1,310.00	1,310.00
Paper	30.5	52.6	68	71.5	75
Ammonia	33.6	46	38	41	44
Ethylene	4.7	7.6	13	16.5	20
Glass	9.1	17.5	27.5	18.8	10.1
Total	806.4	1,530.70	1,907.70	1,912.50	1,918.20

Variable: Iron and Steel: Final Energy Intensity (Tonne of Coal Equivalent per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
All	0.8	0.7	0.7	0.6	0.6

Variable: Aluminium: Final Energy Intensity (Tonne of Coal Equivalent per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
All	9.6	8.5	8.4	8.3	8.2

Variable: Cement: Final Energy Intensity (Tonne of Coal Equivalent per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Rotary kilns	0.2	0.2	0.2	0.1	0.1
Shaft kilns	0.2	0.1	0.1	0.1	0.1

Variable: Paper: Final Energy Intensity (Tonne of Coal Equivalent per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
All	0.9	0.8	0.8	0.7	0.7

Variable: Ethylene: Final Energy Intensity (Tonne of Coal Equivalent per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Naphtha	1.2	1	0.9	0.9	0.9

Variable: Flat Glass: Final Energy Intensity (Tonne of Coal Equivalent per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Flat	0.5	0.5	0.4	0.4	0.4

Variable: Coal and Coke Feed Stock: Final Energy Intensity (Thousand Megajoule per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal unspecified	34.2	32.4	30.8	29.2	27.8
Electricity	4.7	4.4	4.2	4	3.8
Heat	3.8	3.6	3.4	3.2	3.1

Variable: NG Feed Stock: Final Energy Intensity (Thousand Megajoule per Tonne)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Natural Gas	41.7	39.5	37.5	35.7	33.9
Electricity	0.8	0.7	0.7	0.6	0.6
Heat	0.6	0.6	0.5	0.5	0.5

Variable: Fuel Oil Feed Stock: Final Energy Intensity (Tonne of Oil Equivalent per Tonne
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Heavy Oil	0.7	0.7	0.6	0.6	0.6
Electricity	0.1	0.1	0.1	0.1	0.1
Heat	0	0	0	0	0

Variable: Iron and Steel: Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal unspecified	30.5	30.5	30.5	30.5	30.5
Coke	56	56	56	56	56
Heavy Oil	3	3	3	3	3
Natural Gas	0.7	0.7	0.7	0.7	0.7
Electricity	9.8	9.8	9.8	9.8	9.8
Total	100	100	100	100	100

Variable: Aluminium: Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal unspecified	48	48	48	48	48
Metalurgical Coke	3	3	3	3	3
Electricity	45	45	45	45	45
Diesel	1	1	1	1	1
Heavy Oil	3	3	3	3	3
Total	100	100	100	100	100

Variable: Paper: Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal unspecified	88	88	88	88	88
Heavy Oil	0	0	0	0	0
Natural Gas	0	0	0	0	0
Biomass unspecified	0	0	0	0	0
Electricity	12	12	12	12	12
Heat	0	0	0	0	0
Total	100	100	100	100	100

Variable: Cement: Activity Level (% Share of Tonnes)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Rotary kilns	19.5	47.5	55	62.5	70
Shaft kilns	80.5	52.5	45	37.5	30
Total	100	100	100	100	100

Variable: Cement Rotary kilns: Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal unspecified	89.7	89.3	88.8	88.4	88
Electricity	10.3	10.7	11.2	11.6	12
Heat	0	0	0	0	0
Total	100	100	100	100	100

Variable: Cement Shaft kilns: Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal unspecified	89.5	88.6	87.7	86.8	85.9
Electricity	10.5	11.4	12.3	13.2	14.1
Heat	0	0	0	0	0
Total	100	100	100	100	100

Variable: Ethelene (Naphtha): Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Naphtha	62.5	59.8	57.1	53.5	50
Electricity	18.7	20	21.4	23.2	25
Heat	18.8	20.2	21.5	23.3	25
Naphtha Feed Stock	0	0	0	0	0
Total	100	100	100	100	100

Variable: Flat Glass: Fuel Share (Fuel Share)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal unspecified	97.1	97.1	97.1	97.1	97.1
Heavy Oil	0	0	0	0	0
Natural Gas	0	0	0	0	0
Electricity	2.9	2.9	2.9	2.9	2.9
Heat	0	0	0	0	0
Total	100	100	100	100	100

Transportation

Passenger

Variable: Cars: Activity Level (% Share of Passenger-kms)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	100	99	92	70	40
Diesel	0	1	5	8	18
Gasoline Hybrid	0	0	3	22	42
Ethanol	0	0	0	0	0
Total	100	100	100	100	100

Variable: Taxis: Activity Level (% Share of Passenger-kms)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	94	84	66	48	28
Natural Gas	1	12	32	52	72
LPG	5	4	2	0	0
Total	100	100	100	100	100

Variable: Bus: Activity Level (Billion Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Heavy Duty Bus	34.7	82.1	84.6	42.8	0
Medium Duty Bus	18.7	320.8	477.6	543.9	580
Light Duty Bus	295.8	425.7	84.5	0	0
Minibus	128.5	517.9	1,102.90	1,480.20	1,522.80
Total	477.7	1,346.50	1,749.60	2,066.80	2,102.80

Variable: Cars: Final Energy Intensity (Megajoule per Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	1.2	1.2	1.2	1.2	1.2
Diesel	0.9	0.9	0.9	1	1
Gasoline Hybrid	0.5	0.5	0.5	0.6	0.6
Ethanol	1.2	1.2	1.2	1.2	1.2

Variable: Taxis: Final Energy Intensity (Megajoule per Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	1.2	1.2	1.2	1.2	1.2
Natural Gas	0.4	0.4	0.4	0.4	0.4
LPG	0.4	0.4	0.4	0.5	0.5

Variable: Gasoline Car: Final Energy Intensity (Megajoule per Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	0.4	0.4	0.4	0.4	0.4

Variable: Heavy Duty Bus: Final Energy Intensity (Megajoule per Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	0.2	0.2	0.2	0.3	0.3
Diesel	0.2	0.2	0.2	0.2	0.2

Variable: Medium Duty Bus: Final Energy Intensity (Megajoule per Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	0.3	0.3	0.3	0.4	0.4
Diesel	0.2	0.2	0.3	0.3	0.3
Natural Gas	0	0	0	0	0

Variable: Light Duty Bus: Final Energy Intensity (Megajoule per Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	0.2	0.2	0.2	0.3	0.3
Diesel	0.2	0.2	0.2	0.3	0.3
Natural Gas	0.1	0.1	0.1	0.1	0.1

Variable: Minibus: Final Energy Intensity (Megajoule per Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Gasoline	0.3	0.3	0.4	0.5	0.6
Diesel	0	0	0	0	0
Natural Gas	0.1	0.1	0.2	0.2	0.2

Variable: Urban: Stock of Vehicles (units)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Cars	4.5	9.2	18.6	39.5	72.1
Taxis	0.8	1.1	1.5	1.9	2.2
Motorcycles	14.8	24.2	32.2	39.7	45.2
Bus	0	0	0	0	0
Total	20.1	34.4	52.4	81.1	119.6

Variable: Rural: Stock of Vehicles (units)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Cars	0.6	1.3	2.6	4.1	5
Motorcycles	22.9	40.7	59.6	80.8	101.4
Total	23.5	42	62.1	84.9	106.4

Variable: Bus: Stock of Vehicles (units)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Heavy Duty Bus	0	0	0	0	0
Medium Duty Bus	0.1	0.1	0.2	0.3	0.3
Light Duty Bus	0.4	0.6	0.1	0	0
Minibus	0.4	1.7	4	6.2	7.6
Total	0.9	2.4	4.4	6.5	7.9

Variable: Rail: Activity Level (Billion Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Intercity	454.2	566.7	638.1	756.4	876.8
Local	0.6	0.8	0.9	1	1.2
Total	454.8	567.5	638.9	757.4	878

Variable: Water: Activity Level (Million Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Inland Waterways	6,816.60	7,420.50	7,799.00	6,977.80	5,992.00
Coastal Waterways	2,683.40	2,914.40	3,063.10	2,740.60	2,353.40
Total	9,500.00	10,334.90	10,862.10	9,718.40	8,345.40

Variable: Air: Activity Level (Billion Passenger-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Domestic	73.8	141.4	227.1	318.6	442.6
International	23.3	42.2	67.8	95.2	132.2
Total	97.1	183.6	295	413.7	574.8

Freight

Variable: Trucks: Activity Level (Billion Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Trucks	92.4	187.2	354.4	574.7	805.1

Variable: Trucks: Stock of Vehicles (units)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Trucks	1.7	3.4	6.1	9.2	12.6

Variable: Rural: Stock of Vehicles (units)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Trucks	0.9	1.1	1.3	1.5	1.7
Tractor	0.8	1.1	1.3	1.6	1.9
Rural Vehicles	0	0	0	0	0
Total	1.8	2.1	2.6	3.1	3.6

Variable: Trucks: Stock of Vehicles (units)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Heavy Duty Trucks	0.2	0.7	1.2	1.9	2.7
Medium Duty Truck	1.3	1.2	0.9	0.5	0.2
Light Duty Trucks	2	2.6	3.4	4.2	5.1
Mini Trucks	1	1.4	1.3	1	0.7
Total	4.6	5.8	6.7	7.7	8.7

Variable: Intercity: Activity Level (Billion Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal	380.6	588.8	849.2	1,147.20	1,395.80
Oil	81.6	119.2	167.2	223.8	285.6
Coke	40.2	50.8	61.8	71.6	79
Other	809.2	1,226.20	1,352.20	1,314.00	1,348.60
Total	1,311.60	1,985.00	2,430.40	2,756.60	3,109.00

Variable: Local: Activity Level (% Share of Tonne-kms)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Steam	2.7	0.3	0.3	0.3	0.3
Diesel	97.3	99.7	99.7	99.7	99.7
Electricity	0	0	0	0	0
Total	100	100	100	100	100

Variable: Inland Waterways: Activity Level (Billion Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal	17.2	21.6	26.1	30.4	34.4
Oil and Oil Products	12.9	15.1	29.6	41.5	58.3
Crude Oil	12.9	15.1	25.6	34.2	45.8
Other	129	146.4	158.1	159.7	158.9
Total	172.1	198.2	239.4	265.9	297.3

Variable: Coastal Waterways: Activity Level (Billion Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Coal	120.4	212.4	313.6	439.8	588.6
Oil and Oil Products	48.3	83.1	133.8	179	228.5
Crude Oil	39.6	57	84.5	118.5	158.6
Other	278.5	445.5	426.9	368.7	263.6
Total	486.9	798	958.8	1,106.10	1,239.30

Variable: Air: Activity Level (Billion Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Domestic	2.1	3.3	5.8	8.1	11.3
International	2.9	4	7	9.9	13.8
Total	5	7.3	12.8	17.9	25.2

Variable: Pipeline: Activity Level (Million Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Crude Oil	59.2	69.4	102	148.5	208.3
Oil Products	1	3.1	8	16	25.8
Natural Gas	2.8	8.2	17.2	27.7	35.3
Other Gas	0	0	0	0.1	0.1
Total	62.9	80.7	127.2	192.3	269.5

Variable: Trucks: Final Energy Intensity (Megajoule per Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Diesel	2.3	2.3	2.3	2.2	2.1
Gasoline	2.3	2.3	2.3	2.2	2.1

Variable: Rail Final Energy Intensity (Megajoule per Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Steam	0.3	0.3	0.3	0.3	0.3
Diesel	0.1	0.1	0.1	0.1	0.1
Electricity	0.1	0.1	0.1	0.1	0.1

Variable: Rail Final Energy Intensity (Megajoule per Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Steam	0.3	0.3	0.3	0.3	0.3
Diesel	0.1	0.1	0.1	0.1	0.1
Electricity	0.1	0.1	0.1	0.1	0.1

Variable: Domestic Air : Final Energy Intensity (Megajoule per Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Jet Kerosene	17.3	16.5	15.6	14.8	13.9
Avgas	16.6	16.6	0	0	0

Variable: International Air: Final Energy Intensity (Megajoule per Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Jet Kerosene	17.3	16.5	15.6	14.8	13.9
Avgas	16.6	16.6	0	0	0

Variable: Water: Final Energy Intensity (Megajoule per Tonne-km)
Scenario: Ref
Region: All Regions

	2000	2005	2010	2015	2020
Diesel	0.3	0.2	0.2	0.2	0.2